The Work of Playful Science in Nineteenth-Century Britain

by

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Preface

Over the course of this dissertation, I have often felt like Ben Rogers, Tom Sawyer's young friend. In Mark Twain's famous whitewashing scene, Ben is puzzled by the elusive division between "work" and "play." "Ain't *that* work?"[1] Ben asks, watching Tom pretend to enjoy the chore of painting a fence. Twain's ostensible moral to this scene is that "Work consists of whatever a body is obliged to do, and that Play consists of whatever a body is not obliged to do."[2] I say "ostensible" because Twain immediately complicates this simple lesson by suggesting that perhaps it is not obligation, but rather the promise of wages, that turns play into work: "There are wealthy gentlemen in England who drive four-horse passenger-coaches twenty or thirty miles on a daily line […] because the privilege costs them considerable money; but if they were offered wages for the service, that would turn it into work."[3] Tom, however, in his attempt to avoid work by tricking the other boys into painting the fence for him, *has* received compensation. In exchange for letting the boys paint the fence, he is given marbles, a bit of glass, a key, a fragment of chalk, and other odds and ends that for Tom have value. Tom's refusal to work—the trick he has played on his friends—has material rewards. So, has he avoided work or not? The division between "work" and "play" slips away.

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[1] Mark Twain, *The Adventures of Tom Sawyer* (New York: Pocket Books, 2005), 19.
[2] Twain, *Tom Sawyer*, 21.
[3] Twain, *Tom Sawyer*, 21.

Discussing the recreations of nineteenth-century scientific practitioners presents a similar problem. As influential play theorist Brian Sutton-Smith has noted, it is impossible to keep some ambiguity from creeping into discussion of play.[4] I have so internalized the Victorian idea that scientific knowledge is produced through work that practitioners' recreations, when tied to scientific practice, begin to feel like a form of work. When discussing scientific practitioners playing with optical toys, spinning tops, imagining absurd thought experiments, or collecting beetles, it is a little too easy to begin interpreting these recreations as fully calculated decisions meant to further scientific labor. To counteract this, I, like many play theorists before me, try to treat the subject in a light, somewhat playful manner.[5] Beginning a work on recreations with the refusal to take the subject too seriously has become, in fact, a somewhat standard opening gambit.

This approach raises its own challenges, especially in an interdisciplinary dissertation like this one. Though my research contributes to the field known as Literature and Science, I myself am not a scientist; and yet here I am, searching through scientific practitioners' old letters and scribbles, revealing them when they are vulnerable: in their recreational pursuits. As I researched, I worried that it might seem that, in my attempt to avoid taking this work too seriously, I was being too presumptuous. In my experience, today's scientists, like most professional workers, enjoy being told that their recreation has a purpose—to a point. I think we all cling to the idea that even our leisure activities might be contributing to our work. There are reasons to criticize this functional approach to the idea of recreations; however, emphasizing the usefulness of recreation has become, for many people, a defense against exploitation and over-

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[4] Brian Sutton-Smith, *The Ambiguity of Play* (Cambridge, MA: Harvard University Press, 1997), 216.

[5] See Susanna Millar, *The Psychology of Play* (Harmondsworth, Middlesex: Pelican, 1971); Vernon Bartlett, *The Past of Pastimes* (S.l.: Archon Books, 1969).

work. Many of the scientific practitioners I have spoken to welcome the idea that their recreational activities are useful because it helps them preserve, at least in some form, a life outside of their work (or the potential of such). But there are limits to the value that people are willing to ascribe to their recreations. Beyond a certain level of generality, people often seem to conflate valuing the recreational activities of scientific practitioners with a dismissal of their work. As an outsider to the sciences, one might ask: who am I to make claims about why scientists play and what value it has?

Literary theorist Roland Barthes addresses a somewhat similar problem in *The Pleasure of the Text* (1975). In considering how to read criticism, Barthes approaches it as a methodological problem of how to address "*reported* pleasure."[6] How can he, as an outsider to the pleasure, hope to understand the pleasure that another has in reading or writing a text? His solution is to fully embrace being a voyeur: to "observe clandestinely the pleasure of others" and "enter perversion." In order to understand the pleasure of others, Barthes must make the act of viewing pleasure a kind of pleasure for himself. Similarly, to explore the recreations of nineteenth-century scientific practitioners, I must be willing to treat the entire dissertation as a kind of game. Taking seriously the idea that recreations might have epistemological or other value for the sciences means that I cannot take myself too seriously. I must bask in the perversity of revealing practitioners in their recreations, and, for a moment, set aside the worry that I might be mistaken for a dilettante who does not understand how serious scientific practice can be.

Refusing to take this dissertation too seriously also offers me another advantage. It lets me jump from point to point and make unique connections. It lets me make digressions, discussing my personal experiences with nineteenth-century play objects or amusing and

[6] Roland Barthes, *The Pleasure of the Text* (New York: Hill and Wang, 1975), 17.

illustrative historical anecdotes. Here is a digression. In the 1940s, when pinball machines were still considered a type of illegal gambling, American store owners began to attach labels to the machines which insisted that they were "for amusement only."[7] This shift from "gambling" to "amusement" had two functions. First, it emphasized the fact that pinball was (supposedly) not a method of making money, and therefore no threat to a wartime country that was increasingly emphasizing labor as a form of patriotism (for instance, through the icon of Rosie the Riveter). And second, this relabeling of pinball as "amusement *only*" worked to present pinball as something so trivial that it was not worth banning. But despite the labels, New York City Mayor LaGuardia had the police department round up the city's pinball machines, shattered some with a sledgehammer, and then dumped the machines into the Hudson River. Apparently, LaGuardia was not convinced that amusement was always innocent. Like those in the nineteenth century, LaGuardia knew that we cannot easily separate any form of play from gambling, work, or serious employment, even if we often act as though these categories were in opposition to one another.

Although I have labelled this section as the "Preface," it is really more of a "Prelude": the introduction to the ludic, the moment before we dive into our play. And as one of my first playful acts, I would like to affix a "for amusement only" label to this dissertation, although not for the reasons store owners labelled New York's machines. These labels, "for amusement only," demonstrate the stakes of recreation. When recreations are viewed positively, they are often assumed to be innocuous, trivial, merely fun. But there is something volatile about recreations. There is a capriciousness and changeability that is brought out, rather than concealed, when you

[7] Michael Capper et al., "For Amusement Only," 99% Invisible, PRX, 2014, https://99percentinvisible.org/episode/for-amusement-only/.

attempt to restrict their purpose. A pinball machine that insists that it is “for amusement only” immediately ceases to be “for amusement only.” It begins to do new cultural work. It becomes a reminder of the less salubrious forms of recreation and encourages readers to reconsider what “amusement” means. What does it mean for an object to be “for amusement only”? Can an object exist solely to provide fun, without any alternative functions? This is one value of playfulness. It keeps you thinking. If I earnestly entreat my reader not to take this work *too* seriously, then I am exactly the sort of person whose earnestness cannot be trusted. Binaries collapse. Do I *seriously* think that it is important that we not take recreations too *seriously*? The language that we have for discussing recreations never seems to be adequate.

It can be hard to live with this ambiguity, especially as one is drafting an opening for their dissertation. One danger of putting the label “for amusement only” on this dissertation is that it may be read as an acknowledgement that, for all the effort involved, there are questions raised by this dissertation that I will not be able to completely answer. But perhaps this was inevitable. As historian of science Hans-Jörg Rheinberger has pointed out: “Forewords are afterthoughts… They try to impose a closure on what until then could be considered work in progress. Yet by this very gesture they keep the game going.”[8]

[8] Hans-Jörg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford: Stanford University Press, 1997), 11.

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Abstract

The Work of Playful Science in Nineteenth-Century Britain evaluates the function of play in nineteenth-century science, at a time when practitioners increasingly described themselves as "scientific workers" and their practice as "work." I argue that, just as nineteenth-century popularizers of science were able to make use of play to teach children about science, scientific practitioners were able to make use of play to construct scientific knowledge and model how to become a scientific worker. I demonstrate that scientific practitioners used toys as experimental apparatus; they constructed ludicrous thought experiments that blur the line between entertainment and elucidation; and they wrote autobiographies that suggest that youthful hobbies and university bacchanals can be understood as part of the development of scientific practitioners.

The introduction outlines existing narratives about the function of work and play in nineteenth-century British science. Against the grain of these narratives, I propose three benefits that practitioners found in blending science with play in science writing: it encourages readers to craft toys that let them see natural phenomena they could not see before; it allows scientific writers to include absurdities that promote readers' engagement; and it helps model how children might develop into scientific practitioners as adults. The first chapter uses computational analysis to contextualize the relationship between science, play, and work, revealing that science remained more closely associated with play than with work in popular science texts aimed at young people. The second chapter analyzes one such text: John Ayrton Paris's *Philosophy in Sport Made Science in Earnest* (1827). This work, frequently cited in nineteenth-century writing

as an example of the blending of science and play, demonstrates the benefits of playful science for children and acts as a paradigmatic example. The third chapter considers physicist James Clerk Maxwell's decision to label two of his experimental apparatuses in the 1850s as "tops," and suggests that, like Paris, he found playful science useful in encouraging others to build their own experimental apparatus and to see phenomena they otherwise would have missed. The fourth chapter develops the connection between Maxwell and physicist William Thomson (later known as Lord Kelvin) by appraising the thought experiment known as Maxwell's Demon; herein, the claim is that Thomson's addition of absurd, unnecessary details in the 1870s and 1880s actually encouraged readers to dwell on the thought experiment by reworking it repeatedly. The fifth chapter contends that play has special significance in Charles Darwin's life writing in the 1870s, in effect, making the case that Darwin includes details of his youthful recreations because he understood play to be an important part of his development into a scientific worker.

In short, *The Work of Playful Science in Nineteenth-Century Britain* reveals that our understanding of nineteenth-century British science is incomplete if we do not consider the benefits of their recreational pursuits: what we might call the work of scientific practitioners' play in nineteenth-century Britain.

Introduction

I. Nineteenth-Century Science Can Be Fun

It can sometimes seem that science advocates, popularizers, and educators are constantly trying to convince their publics that practicing science is not the stultifying, laborious work it is assumed to be. Take, for instance, a quote from American astronaut Mae Jemison that sometimes circulates in such discussions of the playful side of science. In an interview with the *Chicago Tribune* in 1994, Jemison, describing her goals for a science camp she was promoting for high school students, suggested that the idea of scientists being not fun was simply a stereotype and insisted that "some of the most fun people [she knows] are scientists."[1] Jemison's correction is incontrovertible. Of course, scientists *can* be fun. They play games and amuse themselves like anyone else. There should not be anything strange about the fact that some of the most fun people an astronaut knows happen to be scientists. But for most careers, such a reminder would almost seem a non sequitur, even when publicizing a camp for teenagers. As a scholar of nineteenth-century literature, I have yet to read any news articles that make the case that scholars in my field can be fun (and I am afraid this is not because the pleasures of reading Victorian novels are universally acknowledged). Why do simple assertions of scientists' capacity to have fun come across as a challenge to understandings of what scientists are like?

The difficulties we seem to have today overcoming this association of science and work have their origins in the nineteenth century. Historians of nineteenth-century science and

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[1] Jon Anderson, "Mae Jemison's on a Mission with Science Camp, Ex-Astronaut Wants to Jettison Nerdy Image," *Chicago Tribune*, 26 Apr. 1994, http://search.proquest.com/docview/283780021?pqorigsite=summon&accountid=14667.

scholars of Victorian culture have chronicled the nineteenth century as a time in which science professionalized, shifting from a pastime for leisured individuals into a vocation or job.[2] This did involve some shifts in the actual business of science: scientific practitioners were increasingly likely to fund their research and receive wages through a university or the state, instead of relying on their independent income. But the way that scientific practice was conceptualized and represented also changed, as Lorraine Daston and Peter Galison argue in *Objectivity* (2007). Their influential study of the different characteristics of 'objective' scientific knowledge in different time periods posits that nineteenth-century scientific practitioners began to associate objective science with the figure of "the indefatigable worker, whose strong will turns inward on itself to subdue the self into a passively registering machine."[3] As part of this shift, English-speaking scientific practitioners in the United States and Britain embraced the word *work* as the appropriate description of their activities with enthusiasm. Ruth Barton observes in her study of the language of scientific professionalization that the assumption that scientific practitioners *worked* was so central to these figures' sense of identity that *scientific worker* and *worker in science* became two of the popular names for this group, before *scientist* became the common appellation at the end of the century.[4] The one exception to this insistence that science is work was in popular science – especially popular science aimed at children – where the idea of practicing science as a form of rational recreation was popular.

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[2] Jack Morrell, "Professionalisation," in *Companion to the History of Modern* Science, ed. Robert Cecil Olby et al. (London: Routledge, 1990), 982.

[3] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010), 44.

[4] Ruth Barton, "'Men of Science': Language, Identity, and Professionalization in the Mid-Victorian Scientific Community," *History of Science* 41 (2003): 87. Emphasis in original. Sydney Ross has demonstrated that although William Whewell first coined the term scientist in 1833, the term did not become popular with American scientific practitioners until the late-nineteenth century and was not generally used in Britain until around 1910 (Sydney Ross, "Scientist: the Story of a Word," *Annals of Science* 18, no. 2 (1962), 75). Because terms like "men of science," "scientific worker," and "scientist" refer to specific historically located identities, I generally follow Steven Shapin's strategy of referring to 'scientific practitioners' when I am speaking generally about those involved in the construction of scientific knowledge (see Shapin, "'A Scholar and a Gentleman': The Problematic Identity of the Scientific Practitioner in Early Modern England," *History of Science* 29, no. 3 (1991)).

Of course, this idea that scientific practice is *work* was entirely contingent. Scientific practice does not *need* to be conceived of or described as work and being a hard worker does not guarantee successful science. As sociologist Max Weber recognized in his famous lecture on "Science as a Vocation" (1922), a scientific practitioner "may be an excellent worker and never have had any valuable idea of his own."[5] In fact, Daston and Galison argue that around the late-nineteenth and early-twentieth century, scientific practitioners began to replace paeans to hard work and self-sacrifice with claims that they could not even distinguish their work from their play.[6] But as Daston and Galison also emphasize, this does not mean that the previous understanding of science disappeared. By this point, the idea of science as work had become engrained in the popular idea of science. It is this assumption that scientific practice is work that has made the relationship between science and playfulness so fraught. If science is a form of work or labor, it is easy to assume that work's antitheses —playfulness, recreation, amusement, and all the other forms of 'fun'— must be antithetical to scientific practice. But of course, as science advocates continue to remind us, it is not.

In this dissertation, I make my own contribution to the "science can be fun" discourse by revising one aspect of Daston and Galison's history. I analyze the writings of nineteenth-century British scientific practitioners to demonstrate that, even though many aligned scientific practice with work, most scientific practitioners throughout the century benefited from the advantages that activities undertaken primarily for fun or pleasure afforded. In the chapters that follow, I argue that, just as nineteenth-century popularizers of science were able to make use of play to teach children about science, adult scientific practitioners were able to make use of play to

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[5] Max Weber, "Science as a Vocation," in *Max Weber: Essays in Sociology*, ed. H.H. Gerth and C. Wright Mills (New York: Oxford University Press, 1946).
[6] Daston and Galison, *Objectivity*, 46.

construct scientific knowledge and model how to become a scientist. I demonstrate that scientific practitioners used toys as experimental apparatus; they constructed ludicrous thought experiments that blur the line between entertainment and elucidation; they wrote autobiographies that suggest that youthful hobbies and university bacchanals can be understood as part of the development of scientific practitioners. Through my investigation of nineteenth-century science writing and the objects scientific practitioners played with, I demonstrate that our understanding of nineteenth-century British science is incomplete if we do not consider the benefits of their recreational pursuits, or, what I am calling the work of scientific practitioners' play in nineteenth-century Britain.

II. Influences and Method

In 1938, the Dutch historian Johann Huizinga described the nineteenth century, in his influential work, *Homo Ludens*, as an overly serious time that left "little room for play."[7] It is not difficult to find quotes from nineteenth-century British writers that seem to support this assertion by denoting work as the defining concept of the time. Thomas Carlyle's *Past and Present* (1843) asserts that for the modern worker, there is "no other knowledge but what thou hast got by working" and that "Labor is Life."[8] In Edward Bulwer-Lytton's *Lucretia* (1846) "knowledge without toil, if possible, were worthless."[9] In Samuel Smiles' *Self-Help* (1859) "drudgery [… is] the price of success."[10] In Thomas Huxley's essay "Capital—The Mother of Labor" (1890) "[i]t is… no mere metaphor to say that man is destined for a life of toil."[11]

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[7] Johan Huizinga, *Homo Ludens: A Study of the Play Element in Culture* (Boston: Beacon Press, 1950), 191.
[8] Thomas Carlyle, *Past and Present* (New York: New York University Press, 1977), 197.
[9] Edward Bulwer-Lytton, *Lucretia, or the Children of the Night* (London: Saunders and Otley, 1846), vii.
[10] Samuel Smiles, *Self-Help: With Illustrations of Character and Conduct* (London: Ward Lock, 1859), 101.
[11] Thomas Huxley, "Capital--the Mother of Labour," in *Collected Essays* (New York: D. Appleton, 1897), 147.

Many scholars have since challenged Huizinga's description and revealed how playful nineteenth-century Britain could be. Much of this scholarship has focused broadly on nineteenth-century British culture, often using literary fiction as the primary evidence for analysis. For example, Nancy Morrow's *Dreadful Games* (1988) uses theories of play as the foundation for interpreting nineteenth-century novels.[12] More recently, in *The World in Play* (2012), Matthew Kaiser explored writings by figures like Emily Brontë and Oscar Wilde to argue that the Victorian period was a ludic world in flux, in which different forms of play were valued for different (sometimes contrasting) reasons.[13] Sally Shuttleworth's *The Mind of the Child* (2010) also points out that Victorian Britain was the origin of important scientific theories of play, such as biologist Herbert Spencer's surplus energy theory, in which organisms play to expend excess energy by acting out instinctive roles, or physiologist George Romanes's recapitulation theory, in which play is animals mirroring the trivial instincts habitually performed by their evolutionary ancestors.[14] But the play *of* nineteenth-century scientific practitioners has primarily appeared in two strands of scholarship: scientific biographies and nineteenth-century Literature and Science.

First, scientific biographies. Because biographies often attempt to give a full picture of their subjects, they frequently allude to the recreations their subjects enjoyed. These details are often initially captured in biographies written during or shortly after the practitioner's life. For example, Lewis Campbell and William Garnett discuss the play of physicist James Clerk Maxwell at length in *The Life of James Clerk Maxwell* (1882). Later scientific life writing by scholars often preserves these details.

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[12] Nancy Morrow, *Dreadful Games: The Play of Desire in the Nineteenth-Century Novel* (Kent, OH: Kent State University Press, 1988).
[13] Matthew Kaiser, *The World in Play: Portraits of a Victorian Concept* (Stanford: Stanford University Press, 2012).
[14] Sally Shuttleworth, *The Mind of the Child: Child Development in Literature, Science, and Medicine, 1840-1900* (Oxford: Oxford University Press, 2010).

Second, nineteenth-century Literature and Science (LS). LS is part of the constellation of humanistic approaches to the study of science, including Science Studies, Science and Technology Studies (STS, also known as Science, Technology, and Society Studies), the Sociology of Scientific Knowledge (SSK), and History of Science and Technology (HTS). There is no stable relationship between these fields: all of them have, at one time or another, presented themselves as interdisciplinary, embracing scholars from history, philosophy, anthropology, sociology, literary criticism, and more. Each has also inspired work in other fields. I have seen references to the play of scientific practitioners in many of these fields; however, I see playfulness referenced most frequently in scholarship in LS.

The prevalence of discussion of play in the field of LS can be explained by noting the three assumptions that, according to media scholar June Deery, underlie much of LS scholarship: (1) that an interdisciplinary perspective helps elucidate particular texts or writers; (2) that studying the relations between and across disciplines uncovers their ideologies and values (as well as the ideologies and values of the cultures in which they are embedded); and (3) that literature and science are not stable concepts and have more similarities than their institutional segregation would suggest.[15] Theoretically, work motivated by these assumptions could be undertaken by scholars in various disciplines; however, LS remains a field predominantly inhabited by literary critics, who have tended to focus on the ways in which language shapes the ideologies of science and/or demonstrates the instability of science as a category.[16] In the field of LS, the idea of scientific language as nonfigurative and unambiguous has been thoroughly supplanted by a fascination with scientific practitioners' use of metaphor and ambiguity, which

[15] June Deery, "Twentieth-Century," in *Encyclopedia of Literature and Science*, ed. Pamela Gossin (Westport, CT: Greenwood, 2002), 254.
[16] Deery, "Twentieth-Century," 255.

often has unintended consequences in how scientific knowledge is constructed. In other words, those who study LS often focus on the play of language. For example, in her influential *Darwin's Plots* (1983), Gillian Beer notes the "multivocality" of Charles Darwin's language: "the variability within words, their tendency to dilate and contract across related senses, or to oscillate between significations."[17] Unpacking these shifting significations encourages scholars of Literature and Science to note unexpected playfulness in scientific writing. Beer, for instance, notes that English clergyman William Paley took particular delight in depicting processes of transformation, presenting the unlikeness of butterflies and caterpillars like a fairy tale. Beer describes this as an "element of play and admiration in Paley's discourse" that was later echoed in Darwin's.[18]

The interdisciplinary nature of LS studies often prompts scholars to pay attention to aspects of scientific practitioners' lives that may not initially seem related to their science, such as their recreations. In particular, scholars like Beer have a proclivity to investigate the literary texts their subjects were reading in their leisure time. In *Darwin's Plots*, Beer posits that Darwin may have been "freed from some of the difficulties he experienced in expressing the relation of man to the rest of the natural order by his reading of Dickens."[19] And in *Show Me the Bone* (2016), Gowan Dawson studies biologist Richard Owen's passion for reading serial fiction and argues that these recreations shaped the cognitive processes he employed in his work.[20] But reading is not the only recreation that scholars of Literature and Science have drawn attention to. In *The Poetry of Victorian Scientists* (2013), Daniel Brown argues that Victorian scientists'

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[17] Gillian Beer, *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction* (Cambridge: Cambridge University Press, 2009), 33.
[18] Beer, *Darwin's Plots*, 122.
[19] Beer, *Darwin's Plots*, 56.
[20] Gowan Dawson, *Show Me the Bone: Reconstructing Prehistoric Monsters in Nineteenth-Century Britain and America* (Chicago: University of Chicago Press, 2016), 150-51.

writing of nonsense poetry and play with scientific toys mimicked the childish creation of imagined worlds; play, in this account, becomes a kind of testing ground for the limits of scientific thought.[21] Explicit or implicit understanding that professional scientific practitioners' play was part of how scientific knowledge was developed and disseminated is also visible in the scholarship of literary critics and historians such as David Amigoni's work on scientific life writing, George Levine's work on Charles Darwin, Shuttleworth's work on citizen science, and John Holmes's work on the Pre-Raphaelites and Science.[22]

The area of Literature and Science in which play has probably been most frequently discussed is the scholarship analyzing science texts aimed at children, such as recent work on Victorian popular science by Bernard Lightman;[23] work on instructive books for children in late-eighteenth and early nineteenth-century Britain, by James Secord and Aileen Fyfe;[24] work on the use of fairy tales in popular science by figures like Melanie Keene and Laurence Talairach-Vielmas;[25] and earlier work on rational recreation by Barbara Maria Stafford and Gerard L'E. Turner.[26] This scholarship often notes that playfulness was a tool made use of by scientific popularizers in reaching their audience. Motivated by these works, this dissertation shows that the functions of play in popular science texts aimed at children can help us understand adult

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[21] Daniel Brown, *Poetry of Victorian Scientists: Style, Science, and Nonsense* (Cambridge: Cambridge University Press, 2015).
[22] See David Amigoni, "Writing the Scientist: Biography and Autobiography," in *The Routledge Research Companion to Nineteenth-Century British Literature and Science*, ed. John Holmes and Sharon Ruston (Abingdon, Routledge, 2017); George Levine, *Darwin Loves You: Natural Selection and the Re-enchantment of the World* (Princeton: Princeton University Press, 2006), 65; Gowan Dawson, Chris Lintott, and Sally Shuttleworth, "Constructing Scientific Communities: Citizen Science in the Nineteenth and Twenty-First Centuries," *Journal of Victorian Culture* 20, no. 2 (2015): 248-49; John Holmes, *The Pre-Raphaelites and Science* (New Haven: Yale University Press, 2018).
[23] Bernard Lightman, *Victorian Popularizers of Science* (Chicago: University of Chicago Press, 2007).
[24] See James Secord, "Newton in the Nursery: Tom Telescope and the Philosophy of Tops and Balls, 1761-1838," in *Science in the Nursery: The Popularisation of Science in Britain and France, 1761-1901* (Newcastle: Cambridge Scholars Publishing, 2011); Aileen Fyfe, "Tracts, Classics and Brands: Science for Children in the Nineteenth Century" in *Popular Children's Literature in Britain*, ed. Julia Briggs, Dennis Butts, and M. O. Grenby (Aldershot: Ashgate, 2008).
[25] See Melanie Keene, *Science in Wonderland* (Oxford: Oxford University Press, 2015); Laurence Talairach-Vielmas, *Fairy Tales, Natural History, and Victorian Culture* (New York: Palgrave Macmillan, 2014).
[26] See Barbara Maria Stafford, *Artful Science: Enlightenment Entertainment and the Eclipse of Visual Education* (Cambridge, MA: MIT Press, 1994); Gerard L'E. Turner, *Nineteenth-Century Scientific Instruments* (Berkely, University of California Press, 1983).

scientific practitioners' play. I demonstrate that the science writing of adult practitioners, such as James Clerk Maxwell, William Thomson (Lord Kelvin), and Charles Darwin, takes advantage of the benefits of play that can be observed in science writing aimed at younger audiences.

My thinking on the benefits of playfulness in science writing aimed at children and adults was also heavily influenced by scholarship in the field of Play Studies, another interdisciplinary field which brings together the thinking of psychologists, anthropologists, literary critics, philosophers, folklorists, and more. In this field, the questions of how to define and recognize play and its functions have long been debated by scholars such as Adriano Tilgher, Guiseppe Rensi, Sebastien de Grazia, Gilbert C. Meilaender, Richard Schechner, Roger Caillois, Jeffrey Franklin, James S. Hans, and Gregory Bateson.[27] This dissertation owes a particular debt to the scholarship of Brian Sutton-Smith.

Sutton-Smith's *The Ambiguity of Play* (1997) attempts to explain play by describing the value systems that help human beings determine whether play is worthwhile. He refers to the seven value systems he discusses as "play rhetorics," as they are discourses that can persuade someone that play is valuable. *Play as fate* refers to the assumption that play is valuable because it gives insight into ways in which human lives are dictated by destiny (or by pure luck); this is exemplified in gambling and games of chance. *Play as power* is a rhetoric in which play matters because it is a representation of more serious conflicts that could emerge, such as in a World Cup match between nations. *Play as identity* is a rhetoric that values play as a means of confirming

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[27] Adriano Tilgher, *Work: What It Has Meant to Men through the Ages (Homo Faber)* (New York: Harcourt, Brace and Company, 1930); Sebastian de Grazia, *Of Time, Work, and Leisure*; *Working: Its Meanings and Its Limits* (Garden City, NY: Anchor Books, 1962); Richard Schechner, *Performance Studies : An Introduction* (Florence, UK: Routledge, 2013); Roger Caillois, *Man, Play and Games* (Urbana, IL: University of Illinois Press, 2001); J. Jeffrey Franklin, *Serious Play: The Cultural Form of the Nineteenth-Century Realist Novel* (Philadelphia: University of Pennsylvania Press, 1999); James S. Hans, *The Play of the World* (Amherst: University of Massachusetts Press, 1981); Gregory Bateson, *Steps to an Ecology of Mind* (Chicago: University of Chicago Press, 2000).

the identity of a community of players; an example would be a state fair, in which opportunities for recreation are also opportunities to strengthen community ties. *Play as progress* assumes that play is valuable because it helps children and animals (but not adults) develop. *Play as the imaginary*, often exemplified by creative writing, values play because it provides opportunities for imagination, flexibility, and innovation. *The rhetoric of the self* suggests that activities such as hobbies are valuable because of the personal satisfaction they bring to the player. Finally, *the rhetoric of play as frivolous* often treats playfulness as foolish or trivial, but may give play value by suggesting that it is a protest against the status quo, as seen in ancient trickster characters and in modern calls for playfulness as a corrective to the work ethic.

Sutton-Smith's goal, in delineating these seven value systems, is not trying to create an exhaustive list of reasons play might be valued. But Sutton-Smith is attempting to create as broad a theory as possible, so that all the approaches to play he observes, from ancient history through twentieth century Play Studies, can be placed into one of these seven categories. This allows Sutton-Smith to describe some of the important ideological underpinnings for play and to explain why play is often an ambiguous concept, even within Play Studies. Scholars discussing play may not be aware that they are unconsciously valuing play through one of these rhetorics. For example, someone studying children's play might assume that it is beneficial and natural, without articulating why, because they are considering the activity through the lens of *play as progress*. One might assume that a recreation was undertaken only for personal pleasure because they are viewing the activity through the lens of *the rhetoric of the self*, missing out on other ways the play is valued. Or one might assume that play is always trivial because they are too accustomed to *the rhetoric of play as frivolous*. As Sutton-Smith notes, this last example is especially pervasive.[28]

In *The World in Play*, Kaiser argues that Sutton-Smith's rhetorics have precursors in correspondent logics within the Victorian period and uses these to describe an (admittedly provisional) map of the logics which underpinned the idea of play at this time.[29] As my focus on nineteenth-century British science is narrower than Sutton-Smith's focus on play throughout human history or Kaiser's focus on play in the Victorian period as a whole, my goal is correspondingly more modest. I am not aiming to show that all of Sutton-Smith's rhetorics underlie all nineteenth-century play in the sciences or to describe all the ways play might have been valued in scientific spaces. Instead, this dissertation is more closely focused on the benefits of playfulness that I observe within a few specific cases, which may be applicable to other cases of playful science. However, analyzing playful science with Sutton-Smith's rhetorics in mind did help me to identify some of the benefits of practitioners' play and helped to remind me to be cautious in applying my own assumptions about play to the cases I discuss.

While I was cautious to avoid bringing too many assumptions about the value of play to my research, there was one assumption that I consciously embraced: that when the play of scientific practitioners is made visible in their writing, I should be able to identify some benefit to this play. I was inspired to set this resolution by the work of another play theorist: James S. Hans. Hans's *The Play of the World* (1981) argues that play is "the fundamental activity of man," such that all human activities can be explained as a form of play.[30] As I discuss in the next section, this is not the definition of play used in this dissertation. However, one argument that

[28] Sutton-Smith, *The Ambiguity of Play*, 67, 80.
[29] Kaiser, *The World in Play*, 19.
[30] Hans, *The Play of the World*, x.

Hans makes that I do find illuminating is his claim that "one seeks to play because one believes that the understanding achieved through play is more valuable than the kinds of understanding achieved in other ways [or…] because one finds the understanding achieved in that manner to be a necessary compliment to the understanding achieved through, say, the scientific method or the method of formal logic."[31] Obviously this dissertation rejects Hans's suggestion that the scientific method must be considered separate from play. I will also not be arguing that the only value of playfulness is to foster understanding. However, Hans's assumption that a scholar should be able to explain the play they observe struck me as an important staging ground for this research. Given the importance of describing science as a form of work in the nineteenth century, I argue that it can be assumed that, when playfulness is visible in scientific practice, it is fulfilling some function that could not be achieved in a different way.

III. Defining and Identifying Playful Science

As Sutton-Smith notes, definitions of play often fail: "We all play occasionally, and we all know what playing feels like. But when it comes to making theoretical statements about what play is, we fall into silliness."[32] Many scholars of Play Studies have suggested that it may be impossible to provide a single definition of play that encapsulates all activities referred to under this label. This is the reason philosopher Ludwig Wittgenstein famously used the concept of 'game' as one of his central examples for his theory of "family resemblance": play and its related concepts such as recreation, games, and amusement have no one set of universal characteristics. Overlapping characteristics may appear in many examples of play, but no one characteristic appears in all.[33]

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[31] Hans, *Play of the World*, 12.
[32] Sutton-Smith, *The Ambiguity of Play*, 1.
[33] See Ludwig Wittgenstein, *Philosophical Investigations* (Oxford: Basil Blackwell, 1958), 32e-33e.

When attempts are made to define play — for example, Guiseppe Rensi's definition of play as activity "for itself because of the pleasure or interest which it inspires in us… with no ulterior views"[34] or Adriano Tilgher's argument that play is defined by its triviality, lack of seriousness, and absence of passion[35] — it is usually easy to think of exceptions.

Part of the difficulty is that, as anthropologist and semiotician Gregory Bateson pointed out, human play is not always made explicit by the player. For an act to be interpreted as play, the player must exchange signals carrying the message 'this is play.'[36] The difference between a playful nip and a serious bite entirely depends on whether this signal is communicated. This signal can be communicated explicitly, before, during, or after the action, by using language associated with play to describe an action, such as *play*, *recreation*, *amusement*, or *fun*. For example, one might ask if someone wants to 'play a game.' But more frequently, play is signaled through some form of metacommunication, often determined by what viewers and participants know about the context for the action. The cricket bowler, propelling a cricket ball in the direction of a batter, does not need to say aloud that they are not trying to injure the batter. The context of the game determines how the action is interpreted. The metacommunication involved in play functions like picture frames that tell the viewer not to interpret the picture within in the same way that one might interpret the wallpaper without.

Although Bateson does not discuss the concept of work, work is clearly identified via the same mechanism. Like *play, work* has various meanings but lacks a characteristic that links all possible usages. As literary critic Raymond Williams points out in *Keywords* (1976), *work* is "our most general word for doing something, and for something done… its range of applications

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[34] Qtd. in Tilgher, *Work*, 194.
[35] Qtd. in Tilgher, *Work*, 194.
[36] Bateson, *Steps to an Ecology of Mind*, 179.

has of course been enormous."[37] Like play, work can be communicated explicitly at various times, using words associated with work to describe an action: e.g., *work*, *labor*, *toil*. Williams explains that *labor*, *work*, and *toil* initially all had strong associations with pain and trouble; *labor* and *toil* eventually became "harder words than work," while *work*, in the modern period, began to be defined by "regular paid employment." As this might suggest, work activities, like play activities, are commonly identified through context. The action of growing tomatoes on a working farm may be understood as work, whereas growing tomatoes on an apartment balcony might be interpreted as a recreation. Whether one is receiving payment is often a determinant in identifying work. Other details, such as the age of the potential worker, their freedom of choice in pursuing this activity, or their social class also form the context for interpretation. Of course, these factors often overlap.

Because play and work are frequently understood as antonyms, one can also signal that 'this is play' or 'this is work' by making clear that 'this is not work' or 'this is not play,' respectively. For example, an English professor, asked about a book they are teaching, might say that they 'are not reading it for fun,' to make clear that it is a work activity. But they might describe a different book as something they 'are not reading for work,' to make clear that they view this as a recreation.

This is one of the reasons that the recreations of practitioners of science often seem to come from extra-disciplinary practices. As science professionalized through the nineteenth century (and beyond), it had to carefully define its subjects and spaces for work in opposition to the areas outside the field.[38] A result of this process is that when professionals—those whose

[37] Raymond Williams, *Keywords: A Vocabulary of Culture and Society* (London: Fontana Press, 1983) 334-35.
[38] My thinking on this subject was inspired by Kwame Anthony Appiah's reflections on professionalization in the humanities (Appiah, "Presidential Address 2017: Boundaries of Culture," *PMLA* 132, no. 3 (2017)).

identities are defined by the work they do—perform activities outside their workspaces, their activities can be interpreted as recreations. Of course, interpreting these interdisciplinary actions as forms of play does require knowledge of the context in which one normally works. One cannot say with certainty whether a phrase such as ‘a man wrote a pastiche of Shelley’s *Prometheus Unbound* (1820)’ or ‘a woman collected seaweed specimens’ signal play; but in context, sentences such as ‘the Victorian physicist James Clerk Maxwell wrote a pastiche of Shelley’s *Prometheus Unbound* (1820)’ and ‘the Victorian novelist George Eliot collected seaweed specimens’ can signal play because they lie outside the assumed work practices of these Victorians’ professional identity.

There are also further complications in this understanding of play and work. As some of these examples of the metacommunication involved in work and play make clear, the line between work and play is often blurred. In my batter and bowler example, it may be difficult to determine whether the bowling of a *professional* bowler should count as work, or play, or both. Bateson also argues that there are situations in which even the player may be completely ignorant to the metacommunication provided by the framing.[39] There may be situations in which players are not thinking of themselves as players, and yet the activities can still be interpreted as a form of play. Perhaps the greatest complication is that Bateson observes that many games are constructed not on the premise that an activity is play, but rather on the question “Is this play?”[40] It follows that any activity that raises this question can, at the very least, be investigated as a form of play. In this light, I will be focusing on activities that do include a written signal that the activity might be interpreted as play, such as references to *recreation* or items commonly

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[39] Bateson, *Steps to an Ecology of Mind*, 187.
[40] Bateson, *Steps to an Ecology of Mind*, 182.

associated with play, such as toys or sports equipment. However, further investigations of playful science should take advantage of the fact that anything that *could be* interpreted as play might benefit from being analyzed as play.

In short, I will define the play of scientific practitioners as an activity performed by a scientific practitioner (or those training to become a scientific practitioner) that include elements that might cause them to be interpreted as activities separate from their scientific work and that seem to have been undertaken for pleasure or fun. Furthermore, I follow Matthew Kaiser in arguing that terms like *play*, *recreation*, *leisure*, *amusement*, *games*, and *fun* overlap so often that there is little point in placing an artificial distinction between them.[41] I treat these terms interchangeably. With this definition established, little of this dissertation is devoted to arguing whether an activity is or is not play or work. Rather, I aim to investigate how scientific practitioners' play was used and the various ways in which it functioned.

Importantly, this definition suggests that the difficulty or complexity of a scientific practice should not be used to identify whether or not it is play. This is a pitfall I have seen other play scholars fall into. For example, Giuseppe Rensi argued that because a scientific practitioner acts from the pleasure and passion they feel for their scientific practice, the scientific practitioner is not really a worker but a player.[42] However, philosopher Adriano Tilgher rejected Rensi's claim, arguing that no one could agree with a play theory which asserted that "the scientist[s]… who pass their nights in hand-to-hand struggles with a rebellious angel, toiling in the effort to give form to their imagination, to solve problems which exhaust their minds, are playing and not

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[41] See Kaiser, *The World in Play*, 17. For approaches that do attempt to separate these concepts, see Caillois's *Man, Play, and Games* or Morrow's *Dreadful Games*.
[42] See Tilgher, *Work*, 193.

working."[43] While the language of exhaustion and toiling certainly suggests that this may be interpreted as work, there is no reason that a night such as this could not also be interpreted as a kind of play, in some contexts.

For some, this approach to play will undoubtedly be too narrow. My focus on activities that might be interpreted as separate from practitioners' scientific work would likely not appeal to figures like Rensi, who argues that all scientists are playing.[44] It would likely be even less satisfying to scholars like Hans, who argued that all human activity can be seen as a form of play.[45] But, as the physicist Henri Poincaré pointed out, while both backgammon and science involve rules, this does not imply that science is a game.[46] For the purposes of this dissertation, I will be assuming that the same holds true for the relationship of the sciences to play generally: just because science can be pleasurable does not mean that scientific practice is always play.

For others, my definition of play may appear too broad. The play theorists that support what Sutton-Smith labels "narrow play rhetorics," in which "nothing is play unless contemporaneously so named,"[47] may distrust the fact that my approach does still require some interpretive work. Like many other scholars in the field of Literature and Science, my analysis often involves closely reading published works, archived correspondence, and personal notes to determine practitioners' thoughts and values. When these texts do not explicitly describe an activity as play, I do sometimes use other details, such as clues pointing towards certain emotional states or references to objects typically associated with play, to conclude that an activity was a form of play. At other times, I trust the descriptions of a later biographer in

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[43] Tilgher, *Work*, 195.
[44] See Tilgher, *Work*, 193.
[45] Hans, *The Play of the World*, 13.
[46] See Henri Poincaré, *The Value of Science* (New York: Science Press, 1907), 114.
[47] Sutton-Smith, *The Ambiguity of Play*, 58.

identifying play. In some sections of this dissertation, I even consider practitioners' play by interacting with the objects they played with: recreating these play objects myself or attempting to track down the original objects to gain a better understanding of how fun it would be to interact with them and what benefits may result from playing with these objects.

IV. Outline

Although analyzing scientific practitioner's play involves close attention to their personal and published writing and the objects they played with, this dissertation begins by considering this topic from a distance. Chapter One discusses computational studies designed to verify that in many types of science writing in nineteenth-century Britain, science was more associated with work than with play. I compiled four datasets -- a set of popular science books aimed at young readers, scientific life writing, two scientific periodicals, and a set of scientific life writing books – and used Word2vec natural language processing to create vector space models of each. In these vector space models, each word within the dataset is placed in a multidimensional space, such that words that are more related to one another are closer to one another. It turns out that in three of these four corpora, *work* and *labor* are more related to *science* than *recreation* and *amusement*. The only exception was, as expected, the set of popular science books aimed at young readers. This suggests that nineteenth-century scientific practitioners did, in fact, link science more to work than to play. This also suggests that, if one is to study the function of playful science, popular science works aimed at children would be a good place to begin.

In Chapter Two, "The Profits of Play in John Ayrton Paris's *Philosophy in Sport*," I analyze one popular science text for children: Paris's *Philosophy of Sport Made Science in Earnest* (1827), which was enormously popular throughout the nineteenth century. In this text, a boy named Tom Seymour learns about science when his father reveals the principles behind a variety of toys. I draw attention to three "profits" Paris finds in blending science and play: it encourages his readers to craft toys that let them see things they could not see before, it allows him to include absurdities that promote readers' engagement, and it helps model how children might develop into scientific practitioners as adults. All three of these functions will appear again in the writing aimed at adult scientific practitioners that I discuss in later chapters.

I shift from thinking about popular science for children to thinking about science texts which were aimed at other adult scientific practitioners in Chapter Three, "Play and Experiments on Perception: James Clerk Maxwell and the Secret of the Top." In this chapter, I argue that physicist James Clerk Maxwell's decision to label two of his experimental apparatuses as "tops" (highlighting their possible recreational uses) demonstrates that, like Paris, he found playful science useful in encouraging others to build their own experimental apparatus and in helping others' see phenomena they otherwise would have missed. The "Dynamical Top" Maxwell used to study rotatory motion and the "color tops" he used to study color mixing in the 1850s did not need to be labelled as "tops." In fact, both were substantially different in form from the tops most Victorians played with as children. But I argue that Maxwell's decision to label these objects as "tops" was beneficial to his scientific practice.

Maxwell also makes an appearance in Chapter Four, "Maxwell's Demon, Kelvin's Cricket Bats: Playful Absurdity in Thought Experiments," which discusses the characteristics Maxwell and the physicist William Thomson (later known as Lord Kelvin) made to the thought experiment that Kelvin called "Maxwell's Demon" in the 1870s and 1880s. Specifically, I discuss how some of their descriptions of the Demon, such as Kelvin's description of an "army" of “intelligent demons” each armed with “a molecular cricket-bat”[48] created absurd images that might distract from the goal of this thought experiment: to demonstrate the probabilistic nature of the second law of thermodynamics. However, I argue that the absurd, unnecessary details encourage readers to dwell on the thought experiment, reworking it repeatedly.

Chapter Five, “Diversion or Development? Play and the Scientific Life in Charles Darwin’s *Recollections*” focuses on the text which established the basic pattern for scientific autobiography[49]: the life writing by naturalist Charles Darwin in the 1870s and 1880s. I draw attention to an issue that has been largely overlooked in scholarship on Darwin’s life writing: his decision to include stories of his boyhood and young adult recreations within his autobiography, *Recollections of the Development of my Mind and Character* (1876). I argue that Darwin’s inclusion of these details, and the centrality of the shift from playfulness to work to his autobiography’s structure, demonstrates that Darwin understood play to be an important part of the development of a scientific worker and provides a model that others might follow.

In the Postlude, I discuss the work which remains to be done in investigating scientific practitioners’ play. I have chosen to focus on different kinds of scientific practice – popularizing science aimed at children, designing experimental apparatus, thought experiments, and scientific life writing – in various parts of the century to demonstrate that play could be found in various places in the nineteenth century, even as science was transitioning from avocation into vocation. However, the scientific practitioners discussed in these chapters are all white men belonging to either professional classes or landed gentry, and thus may not provide a very full picture of all the potential benefits of playful science. I hope that this dissertation takes the first steps towards

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48 William Thomson, “Kinetic Theory of the Dissipation of Energy,” *Nature* 9 (1874): 442.
49 Linda H. Peterson, *Victorian Autobiography: The Tradition of Self-Interpretation* (New Haven, CT: Yale University Press, 1986), 159.

addressing how scientific practitioners from various backgrounds, and even in various historical periods, conceived of and benefitted from their play.

Chapter 1 - Locating Work and Play in Four Genres of Nineteenth-Century Scientific Writing

I. Introduction

In the introduction to this dissertation, I made the claim that one of the defining features of nineteenth-century British science was that scientific practice was understood as a form of *work*. My understanding that science and work were associated at this time came primarily from the work of historians of nineteenth-century science. But how have they come to this conclusion? In general, scholarship has relied on descriptions of science by practitioners of that time: particularly those "men of science" who are well-known. For instance, in a study of the language used by "men of science" to assert their professional identity, published in 2003, Ruth Baron supports her claim that scientific practitioners defined themselves as workers by gathering many examples of mid-century practitioners self-describing their field, from periodicals like *Nature* (1869 – present) and *Scientific Opinion* (1868-1870) and within presidential addresses to the British Association for the Advancement of Science (BAAS).[1] While this represents a narrow swath of nineteenth-century British scientific discourse, it is still clear from Barton's examples that descriptions of science as work were prevalent in the nineteenth century. But one cannot determine, from scholarship like Barton's, whether science was more closely associated with work than play.

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[1] Ruth Barton, "'Men of Science': Language, Identity, and Professionalization in the Mid-Victorian Scientific Community," *History of Science* 41 (2003): 87. Emphasis in original.

It is easy to assume that an emphasis on science as work would diminish any associations of science and play. Since the first appearance of the term *play* in the 1785 edition of Samuel Johnson's dictionary, *play* has been understood as a negation of work--"action not imposed; not work; dismission from work."[2] Peter Bailey has argued in *Leisure and Class in Victorian England* (1978) that in the Victorian period, recreation became further extricable from work: leisure was "not only… reduced but relocated in the life-space, forming a separate and self-contained sector in an increasingly compartmentalized way of life."[3] But as the chapters that follow will demonstrate, if one searches for examples of scientific recreations, one can certainly find them. To more fully unpack the context for scientific work and play, this chapter tackles the subject using a different methodology: distant reading.

In this chapter, I share computational studies I performed to investigate the relatedness of science and work and the relatedness of science and recreation across four corpora of nineteenth-century science writing: a set of popular science books aimed at young readers, scientific life writing, two scientific periodicals, and a set of scientific life writing books. Word2vec natural language processing was used on each of these datasets to create four different vector space models, and cosine similarity was used to determine whether the terms *work* and *labor* were more related to *science* than the terms *recreation* and *amusement*.[4] I found that across three of the four corpora, *work* and *labor* were more related to *science* than *recreation* and *amusement*. The one exception, as one might expect, was the set of popular science books aimed at young readers. This suggests that nineteenth-century scientific practitioners did, in fact, link science

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[2] Quoted in J. Jeffrey Franklin, *Serious Play: The Cultural Form of the Nineteenth-Century Realist Novel* (Philadelphia: University of Pennsylvania Press, 1999), 213.

[3] Peter Bailey, *Leisure and Class in Victorian England: Rational Recreation and the Contest for Control, 1830-1885* (London: Routledge & Kegan Paul, 1978), 4.

[4] Technically, because these are sets of British texts, the term of interest was *labour* rather than *labor*. However, I am using the American spelling of the term in the chapter for clarity.

more to work than to play and that, if one is to study the function of playful science, popular science works aimed at children would be a good place to begin.

II. Materials

To better understand the relationship of work and play to nineteenth-century conceptions of science, I wanted to study corpora that could add context to the case studies in the Chapters 2 - 5. To that end, I compiled 4 datasets of texts: a set of popular science books aimed at young readers, the volumes of the *Philosophical Magazine* (1800 - 1900), the volumes of *Nature* (1869 - 1900), and a set of scientific life writing (i.e., biographical and autobiographical) books. I originally collected most of these texts as pdfs from databases such as *Hathi Trust*, *Google Books*, and the *Biodiversity Heritage Library*. I relied on Jeroen Ooms "pdftools" for transforming the pdfs into a form that could be used in R.[5]

Corpus 1 is a corpus of book-length popular science texts, published in Britain for young readers. As Aileen Fyfe and Bernard Lightman note in *Science in the Marketplace* (2007), popular science appeared in a variety of nineteenth-century sites, including lectures, magazines, galleries, public gardens, and museums.[6] Works like Louise Henson et al.'s *Culture and Science in Nineteenth-Century Media* (2004) and Geoffrey Cantor and Sally Shuttleworth's *Science Serialized* (2004) have demonstrated the importance of science popularization in periodicals. In this corpus, however, I focused only on book-length texts, as I found these texts easier to locate. Moreover, many nineteenth-century periodicals are digitized as a complete volume, so including articles would have entailed a significant amount of work separating select articles from the

[5] Jeroen Ooms, "Package 'Pdftools,'" 2020, https://docs.ropensci.org/pdftools/.

[6] Aileen Fyfe and Bernard Lightman, "Science in the Marketplace: An Introduction," in *Science in the Marketplace: Nineteenth-Century Sites and Experiences*, ed. Aileen Fyfe and Bernard Lightman (Chicago: University of Chicago Press, 2007), 5.

volumes in which they were digitized. I avoided including multiple editions of these books, and I used the earliest digitized edition I could find, which unfortunately was not always the first edition. I hoped that this corpus would provide context for John Ayrton Paris's popular science book *Philosophy of Sport Made Science in Earnest* (1827), the subject of Chapter Two.

I determined whether these books were aimed at young readers using a three-step process. First, I relied heavily on the scholarship of figures like Aileen Fyfe and Bernard Lightman to determine which texts should be included. I trusted their judgement about which texts were aimed at young readers and used this as a starting point. Secondly, I used the advertisements which frequently appeared at the end of popular science works to find new texts. If an advertisement stated that a book was suitable for young readers, I considered adding it to my corpus. As a final step, I narrowed my list of possible entries to those that explicitly stated that "children," "juveniles," or "young readers" were their audience. This is not to say that these texts were *only* read by young readers. As Lightman notes, there was no clear-cut line between texts for children and texts for adults, as adults frequently read with children.[7] However, through this three-step process, I was able to construct a corpus which includes several different disciplines, including discussions of plants and animals, natural philosophy, chemistry, and astronomy. Appendix A gives a list of the 56 texts included in my juvenile popular science corpus.

Corpus 2 includes all the nineteenth-century volumes of the *Philosophical Magazine* published between 1800 and 1900. This magazine is also known as the *Philosophical Magazine and Journal*, and *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*. I chose volumes of the *Philosophical Magazine* as one of my datasets because some of

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[7] Bernard Lightman, *Victorian Popularizers of Science* (Chicago: University of Chicago Press, 2007), 124.

James Clerk Maxwell's experiments on color, discussed in Chapter Three, were published in these volumes. I also found this dataset valuable because it is one of the oldest scientific journals published in English, because every volume had been digitized, and because the 191 volumes published in the nineteenth century provided a very robust dataset.

Corpus 3 was constructed for very similar reasons. For this dataset, I retrieved all 61 volumes of *Nature* published in the nineteenth century. I chose to study *Nature* because these volumes include some of the work of William Thomson (Lord Kelvin) on Maxwell's Demon, discussed in Chapter Four.

Corpus 4 is a collection of book length biographical works on the lives of nineteenth-century British scientific practitioners, published in Britain between 1800 and 1899. As literary scholar Richard Altick noted in the 1960s, the nineteenth-century was an "age of biography."[8] *Publisher's Circular* estimated that 363 biographies and histories were published in 1880 alone.[9] There seemed to be biographical compilations for almost every subset of Victorian culture, including "Eminent Women, English Men of Action, Military Biographies, Great Artists, Great Musicians, English Worthies, Men Worth Remembering, [and] Lives Worth Living."[10] But for a long time, work on biography by critics such as Altick focused on literary biography: life writing about "the men and women who have created our literature."[11] Attention to biographies and autobiographies written about and by scientific practitioners has lagged behind. Recently, however, scholars such as Michael Shortland, Richard Yeo, Geoffrey Cantor, Thomas Söderqvist, Oren Harman, Steven Shapin, and David Amigoni have made persuasive cases for

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[8] Richard D Altick, *Lives and Letters: A History of Literary Biography in England and America* (New York: Alfred A Knopf, 1965), 77.
[9] Juliette Atkinson, *Victorian Biography Reconsidered: A Study of Nineteenth-Century Hidden Lives* (Oxford: Oxford University Press, 2010), 4.
[10] Altick, *Lives and Letters*, 77.
[11] Altick, *Lives and Letters*, ix.

further analyzing this important set of texts, sometimes referred to as scientific life writing.[12] In this corpus, I again opted to focus on book-length works, excluding scientific life writing in periodicals, because these texts were easier to locate, and because I could download the entire book instead of taking on the extra burden of extracting the relevant pages from digitized volumes. This corpus includes both biographies and autobiographies, although prosopographies focusing on multiple scientific practitioners were not included.[13] The goal in focusing on this genre was to provide context for the discussion of Charles Darwin's autobiography in Chapter Five.

One challenge in compiling this corpus was that the question of who counts as a "scientific practitioner" (and thus, whose lives count as 'scientific') is not a trivial one. As scholars such as Ruth Barton and Lawrence Goldman have pointed out, nineteenth-century attempts to group scientific practitioners—such as Francis Galton's survey of scientific men or the *Oxford Dictionary of National Biography*—were elitist, favoring social status and membership in scientific societies.[14] Although I have worked against this where I could—for example, by including popularizers such as Charles Kingsley and 'women of science' such as Caroline Herschel -- my corpus has a similar bias. The easiest scientific life writing to find when

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[12] Michael Shortland and Richard Yeo, *Telling Lives in Science: Essays on Scientific Biography* (Cambridge: Cambridge University Press, 1996); Geoffrey Cantor, "Scientific Biography in the Periodical Press," in *Science in the Nineteenth-Century Periodical: Reading the Magazine of Nature*, ed. Geoffrey Cantor et al. (Cambridge: Cambridge University Press, 2004); Thomas Söderqvist, "A New Look at the Genre of Scientific Biography," in *The History of Poetics of Scientific Biography*, ed. Thomas Söderqvist (Aldershot: Ashgate, 2007); Oren Harman, "Scientific Biography: A Many Faced Art Form," *Journal of the History of Biology* 44 (2011); Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008); David Amigoni, "Writing the Scientist: Biography and Autobiography," in *The Routledge Research Companion to Nineteenth-Century British Literature and Science*, ed. John Holmes and Sharon Ruston (Abingdon, Routledge, 2017).

[13] For work on the many life writing genres, see Atkinson, *Victorian Biography Reconsidered*; Vita Fortunati, "Mirror Shards: Conflicting Images between Marie Curies Autobiography and Her Biographies" in *Writing about Lives in Science: (Auto)Biography, Gender, and Genre*, ed. Paola Govani and Zelda Alice Franceschi (Göttingen: V&R UniPress, 2014); Sidonie Smith and Julia Watson, *Reading Autobiography* (Mineapolis, MN: University of Minnesota Press, 2001).

[14] See Barton, "Men of Science," 87; Lawrence Goldman, "A Monument to the Victorian Age? Continuity and Discontinuity in the Dictionaries of National Biography, 1882-2004," *Journal of Victorian Culture* 11, no. 1 (2006): 124.

searching databases is books which have titles that note that their subject was a Fellow of the Royal Society (e.g., *Life and Letters of James David Forbes, F.R.S.* (1873)). Another method I used for building this corpus was to search for the names of nineteenth-century scientific practitioners who were listed as scientific practitioners on *Wikipedia*. Both methods favor the well-connected and well-known. As a result, most of the practitioners described in this corpus were white men from either professional classes or landed gentry. I hope that readers will keep these biases in mind in discussions of this corpus. Appendix B gives a list of the 70 texts included in my corpus.

III. Methods

The terms ‘computational literary studies’ (CLS) and ‘distant reading’ are used to refer to many types of analysis, but as Nan Z. Da notes, CLS usually “entail[] feeding bodies of texts into computer programs to yield quantitative results, which are then used to make arguments about literary form, style, content, or history.”[15] Johanna Drucker explains in her article “Why Distant Reading Isn’t” (2017) that this first means that human beings have to decide how to divide a text into meaningful units that an automatic process can recognize. This process is known as tokenization.[16] Typically, character strings representing individual words act as a project’s tokens. For example, the sentence ‘the quick brown fox jumps over the lazy dog’ might become a list of tokens: ‘the,’ ‘quick,’ ‘brown,’ ‘fox,’ ‘jumps,’ ‘over,’ ‘the,’ ‘lazy,’ ‘dog.’ Once a text or corpus has been tokenized, some kind of algorithm is used to find, match, or count elements in the dataset. The process of determining what elements can be and will be counted is known as

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[15] Nan Z. Da, “The Digital Humanities Debacle,” *The Chronicle of Higher Education* (27 Mar. 2019), https://www.chronicle.com/article/the-digital-humanities-debacle/.
[16] Johanna Drucker, “Why Distant Reading Isn’t,” *PMLA* 132, no. 3 (2017): 629.

parameterization. The entire process of abstracting information from the dataset to create or detect patterns is known as *data mining*.

As Drucker points out, in their simplest form, computational study of written texts might simply match and sort character strings. Drucker's example is an analysis of the word "mother." If one wanted to see how often and in what context "mother" appears in literature in English in the nineteenth century, one might follow these steps: (1) define what corpus will be used to represent "literature in English" (e.g. a collection of novels, a set of periodicals, etc.); (2) write or find a program that can tokenize the texts in the datasets into words, match those tokens to the character string "mother," and count the number of matches in a given time period (say, a publication year); (3) analyze the context and frequency of matches to better understand how usage of the word "mother" changed over time. Note that this last step is conducted by humans, not by the computer. As Drucker argues, the computer's work – finding matches and counting – has little to do with making meaning; that act still requires a human. Drucker describes these kinds of analyses as "blunt instruments of analysis" which are primarily helpful "as departure points for research."[17]

Word2vec, natural language processing introduced by Mikolov et al. in 2013,[18] is a bit more complicated than this, but in essence, it is also feeding texts into a computer to assign quantitative values to each token. However, instead of simply counting the frequency with which a word occurs in a corpus, word2vec represents each word with a vector: a set of numbers that represents where that word sits in a vector space. These vectors are also called *embeddings*. A

[17] Drucker, "Why Distant Reading Isn't," 631.
[18] Tomas Mikolov et al., "Efficient Estimation of Word Representations in Vector Space," 2013, arxiv.org/abs/1301.3781.

neural network model is used to assign these vectors, so that words that are closely associated with one another within the corpus are placed near each other in vector space.

An analogy will help here.[19] Imagine that you are attending a house party. Someone asks you to help them identify the host, so you point toward them. Your pointing could be represented as a set of numbers in two dimensions: for example, (8, 10), signifying that the host is 8 feet east of you and 10 feet north. Of course, we live in a three-dimensional world, so the direction you point to identify the host actually depends on three pieces of information. If you are pointing at the host's head, for example, the vector might actually be (8, 10, 6), signifying that the host is 8 feet east of you and 10 feet north, and is 6 feet tall. In our world, three dimensions is the maximum number that we can imagine, but there is no reason that we cannot keep adding more quantitative information to our vector to better describe where the host would be in a higher dimensional vector space. If the host is speaking at 65 decibels, we might describe their position in a 4-dimensional space as (8, 10, 6, 65). Let's say they have blond hair. Colors are often represented in RGB color code a set of three numbers, and a blond hair color could be represented by (250, 240, 190). We might add this information to our vector space as well, so that it is clear that the host is a 8 feet east, 10 feet north, standing at 6 feet tall, speaking at 65 decibels, and whose hair color can be represented by the RGB color code (250, 240, 190): a vector in a 7-dimensional vector space of (8, 10, 6, 65, 250, 240, 190). Let's call this $\boldsymbol{h}$.

It is important to note that, in this analogy and in the vector space created by word2vec, there are multiple ways to be close to the position of some other vector. For example, imagine three guests. Guest A is the person the host is talking to. They are standing only two feet east of

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[19] This analogy was inspired by a similar analogy using personality embeddings in Jay Alammar, "The Illustrated Word2vec," 2019, https://jalammar.github.io/illustrated-word2vec/.

the host, but they are also shorter, are speaking more softly, and have brown hair. They are represented by the vector ***a* =** (6, 10, 5.5, 60, 56, 16, 28). Guest B is the identical twin of the host. They have the same height and hair color and are speaking at the same volume, but they are 8 feet south of the host. Their vector is ***b*** = (8, 2, 6, 65, 250, 240, 190). Guest C, a neighbor who has not yet left their house to join the party, is whispering goodnight to their child on their way out the door. They are much shorter than the host and have shocking pink hair. Their vector is ***c*** = (-120, -125, 5, 30, 255, 16, 240). The vectors for Guests A and B should be more similar to the vector for the host than the vector for Guest C is. If I identify the host by pointing, someone might misunderstand where I was pointing to and assume I was talking about Guest A. If I identify the host by saying "it's the 6-foot-tall person with blond hair," someone might misunderstand and assume I was talking about Guest B. There is very little chance of mistaking the host for Guest C. But is Guest A more similar to the host than Guest B is?

Cosine similarity provides a way of measuring these relationships. Cosine similarity is a measure of the similarity between two vectors and is the most common measure of similarity between word embeddings.[20] It is defined as the cosine of the angle between the two vectors, which can range from -1 to 1. Sometimes it is defined as the inner product of two vectors which have been normalized so that both have a length of 1, which means the same thing. So, for example, the cosine similarity of ***h*** with itself is 1. Two vectors ***h*** would have an angle of 0° between them, so they are perfectly similar. The cosine similarity of ***h*** and ***a*** is 0.7626841. The cosine similarity of ***h*** and ***b*** is 0.9998008. The cosine similarity of ***h*** and ***c*** is 0.7186148. As we expected ***a*** and ***b*** are more similar to ***h*** than ***c*** is. But the cosine similarity of ***h*** and ***a*** and the

[20] Dan Jurafsky and James H. Martin, *Speech and Language Processing* (2021), https://web.stanford.edu/~jurafsky/slp3/.

cosine similarity of ***h*** and ***c*** are surprisingly close. Apparently, in this vector space, brown hair and blonde hair are very dissimilar.

In my analogy, I imagined someone constructing a vector to identify the host of a party; word2vec must do the same, but for a word in the corpus. Here is the short version of how this works. Text data is uploaded to the computer. Parameters for the vector space model are set, including how many dimensions the vectors should have, how many iterations the vector space model should test, and what "window" the vector space model should look at to determine the word embeddings. For the vector space models used in this chapter, the vector space model was set to have 200 dimensions for each vector, go through 20 iterations, and have a window of 12 words. To implement the creation of this vector space, I used the word2vec[21] and wordvectors[22] package in R. Word2vec creates embeddings for words in the corpus based on the other words they tend to appear near (within the assigned window). This is because words that occur in similar contexts tend to have similar meanings or to be related to one another, while words that are different in meaning tend to occur in different environments.[23] So in this case, the algorithm uses the 12 words before and after each word to assign the word's vector, improving its accuracy with each iteration. There are two possible models that word2vec can use to compute word embeddings: continuous-bag-of-words (CBOW) and skip-gram. For each target word, CBOW uses the context – all the other words in the window – and uses them to predict the predict what word is likely to appear in the middle. In contrast, skip-gram uses the target word to predict what the context is likely to be. In this chapter, I have used a skip-gram model, as skip-gram tends to be better at finding semantic relationships between words. For example, CBOW is more likely to

[21] Jan Wijffels, BNOSAC, and Max Fomichev, "Package 'word2vec,'" 2 July 2021, https://github.com/bnosac/word2vec.
[22] Ben Schmidt, "wordVectors," 2017, https://github.com/bmschmidt/wordVectors.
[23] Jurafsky and Martin, *Speech and Language Processing*.

put *cup* near *cups* (a syntactical relationship), while skip-gram is more likely to put cup near coffee. As the computer looks at each target word, it gradually trains a classifier that is trying to determine how likely it is that the target word will appear in a certain context. The actual predictions do not matter in word2vec; what matters is that as this classifier is trained, each target word will be assigned certain weights, corresponding to how likely it is that a word will appear in a certain context. And these weights are what are used as the numerical values in the word embeddings. It is important to note that unlike in my party analogy, I cannot know what each of the dimensions of the vector is actually encoding, although it is sometimes possible to speculate based on similarities between words. However, the end result is that words that are related to one another should appear next to each other in the vector space, and the similarity between two embeddings can be measured by their cosine similarity.

Word2vec tends to capture different kinds of relationships. Sometimes scholarship describes cosine similarity in word2vec vector space models as a measure of semantic similarity. In its narrowest conception, semantic similarity refers to a direction-less relationship between two words, in which the words can be swapped in a sentence without changing the truth of a sentence.[24] For example, someone eating a *submarine* sandwich could instead refer to it as a *hoagie* without changing the meaning of the sentence. Words that are semantically similar in this way should have a high cosine similarity. However, word2vec also captures other types of relationships, such as relatedness, antonymy, and meronymy. Semantic relatedness refers to any relationship between terms: *coffee* is clearly related to *cup*, since the two often appear near each other, but one cannot swap *coffee* for *cup* in a sentence like “she drank coffee from her cup”

[24] Fatemeh Torabi Asr, Robert Zinkov, and Michael N. Jones, “Querying Word Embeddings for Similarity and Relatedness,” *Proceedings of NAACL-HLT* (New Orleans, Louisiana: Association for Computational Linguistics, 2018), 675; Jurafsky and Martin, *Speech and Language Processing*.

without changing the meaning of the sentence. Moreover, relatedness is often directional (e.g., the relationship of *broom* to *floor* is not the same as the relationship between *floor* and *broom*) and asymmetric: research shows that *stork* is more likely to cue people to think of *baby* than *baby* is to cue people to think of *stork*.[25] Antonymy refers to words that are opposite in meaning, such as *happy* and *sad*. And meronymy refers to semantic relationships in which one word is part of another: e.g., *bread* and *panini*. Word2vec is not great at capturing these nuances. Antonyms tend to be placed near one another, since they often appear in similar contexts (e.g., *he was happy*, *he was sad*) and because cosine similarity cannot represent asymmetrical relationships.[26] So even though cosine similarity is a measure of the similarity between two vectors, it is more helpful to think of it not necessarily as being about the similarity between word A and word B, but rather as a measure of how much A has to do with B.

In my analysis of these vector space models, three locations within the models were of particular interest: the space where the word *science* was placed, the space where the words associated with work were located (which I call the work space) and the space where the words associated with play are located (which I call the play space). The central question of my analysis is whether the work space is closer to science than the play space is. In other words, is the cosine similarity of the work space and science higher than the cosine similarity of the play space and science? Did my vector space model determine that work is more related to science than play is?

When studying the relationships between terms in a vector space model, it is sometimes helpful to choose a vector which averages at least a couple of word embeddings related to the

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[25] Asr et al., "Querying Word Embeddings for Similarity and Relatedness," 675.
[26] Asr et al., "Querying Word Embeddings for Similarity and Relatedness," 675. Asr et al. suggest finding the cosine similarity between a word and another words' context, instead of the word itself, to capture relatedness.

concept of interest. There is always some randomness in a vector space model: averaging between word embeddings can help to reduce the impact of this randomness. For example, in determining the vector representing the work space, I averaged the word embeddings for the vector associated with *work* and the vector associated with *labor*. *Labor* and *work* were placed close to each other in all my datasets, and by averaging these two-word embeddings, I was better able to define the space in my vector space models where words associated with work tended to appear. One advantage of using a vector space model is that I did not need to worry about whether I was including all possible synonyms of *work* in my analysis, because they should be near this work space regardless.

In choosing my play space vector, I learned that the word *play* itself was not placed in the part of the vector space model relating to recreation, amusement, or fun activities. As psychologist Susanna Millar has pointed out “the term ‘play’ has long been a linguistic waste-paper basket.”[27] It is a term used to refer to many types of activities. As a result, it appears in many different contexts, which meant the models did not always place it near activities pursued for fun. For example, in the *Philosophical Magazine* vector space model, the top ten words close to *play* were *act*, *prominently*, *exercise*, *itself*, *contact*, *come*, *question*, *nature*, *forth*, and *essential*. Some of these, such as *act* and *exercise*, are related to forms of play, but the connection between the other terms and play is much less clear. In contrast, the word *recreation* was situated near more words more obviously related to playfulness. The top ten words close to *recreation* in the *Philosophical Magazine* vector space model were *delight*, *pursuit*, *acquirement*, *agriculture*, *literature*, *amusement*, *architecture*, *student*, *sportsman*, and *enjoyment*. Because

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[27] Susanna Millar, *The Psychology of Play* (Harmondsworth, Middlesex: Pelican, 1971), 11.

recreation and *amusement* tended to appear close to one another in my models, I used the average of these two-word embeddings as the vector representing the play space.

The end result of this process was a new representation of my four corpora, as vector space models. It is important to remember that the vector space models, their word embeddings, and the cosine similarities between vectors in this vector space are best understood not as objective "data" but as what Johanna Drucker has termed *capta*: information which has been 'taken' from another source and reconfigured.[28] These results of a word2vec vector space model will not be perfect. As Drucker emphasizes, in CLS, "quantitative approaches are always limited by the partial, skewed, and heterogenous evidence in the cultural record."[29] Attempts to try to perfect distant readings can in fact be a trap, introducing new biases that lead to less reliable results. Despite errors that might occur, these models were able to expose start points for study and show new aspects of these texts that can guide the rest of this dissertation.[30]

IV. Results

Table 1-1 shares the results of this investigation. As expected, popular science books aimed at youth were the only corpus in which the play space, defined by the terms *recreation* and *amusement*, was more related to *science* than the work space, defined by the terms *work* and *labor*. In the volumes of the *Philosophical Magazine*, in *Nature*, and in my corpus of scientific life writing books, the cosine similarity between the work space and *science* was higher than the cosine similarity between the play space and *science.*

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[28] Drucker, "Humanities Approaches to Graphical Display," *DHQ* 5, no. 1 (2011).
[29] Drucker, "Humanities Approaches to Graphical Display."
[30] Drucker, "Why Distant Reading Isn't," 633.

Corpus	Popular Science Books for Youth	*Philosophical Magazine*	*Nature*	Scientific Life Writing
Cosine Similarity between Work Space and *Science*	0.400567	0.441979	0.45971	0.436279
Cosine Similarity between Play Space and *Science*	0.471047	0.431511	0.308096	0.277404
Difference	-0.07048	0.010468	0.151614	0.158875

Table 1-1: Cosine similarities between work space and *science* and play space and *science*, in the skip-gram vector space models.

V. Discussion

Before discussing my results, I feel I must start by noting that CLS remains one of the most prominent and most divisive strands of the digital humanities.[31] Nan Z. Da has lambasted this field as one rife with methodological issues that "can offer no plausible justification for [its] imprecision and drastic reduction of argumentative complexity."[32] While I do not completely agree with Da's representation of the field, I am cognizant of many of the weaknesses Da draws attention to. In this section, I will explain how one might interpret the cosine similarities I calculated, but also explain some of the complications one should keep in mind when considering these values.

Our vector space model suggests that in the volumes of the *Philosophical Magazine*, in *Nature*, and in the scientific life writing corpus, science is more related to work than to play. This is what I expected, given the scholarship on nineteenth-century science that suggests that scientific practitioners emphasized that science was a form of work. There are some interesting differences between these results. The difference between the cosine similarities in the *Philosophical Magazine* is smaller than the difference in the *Nature* or scientific life writing

[31] Da, "The Digital Humanities Debacle."
[32] Da, "The Digital Humanities Debacle."

corpus. To better understand the differences between these models, I have plotted the 50 words closest to *science* in a two-dimensional space, where the x-axis signifies cosine similarity to the work space, and the y-axis signifies cosine similarity to the play space.

Figure 1-1 gives a sense for why the difference between the cosine similarity between work space and *science* and the cosine similarity between the play space and science is so low. The words closest to *science* are gathered on a diagonal line straight through the plot, suggesting that most of them are about as related to work as they are to play. There are some outliers. *Publication* is far more related to the work space than it is to the play space. This is likely because *publication* can be a synonym for *work* in some contexts. Similarly, *knowledge* is more related to the work space, which is perhaps capturing Daston and Galison's observation that the construction of scientific knowledge had to be justified through hard work in the nineteenth century. But on the whole, there is less separation between words related to science and play than one might expect. Almost all the words most closely associated with *science,* each of which played a role in determining the embedding for *science*, are about as related to work as they are to play.

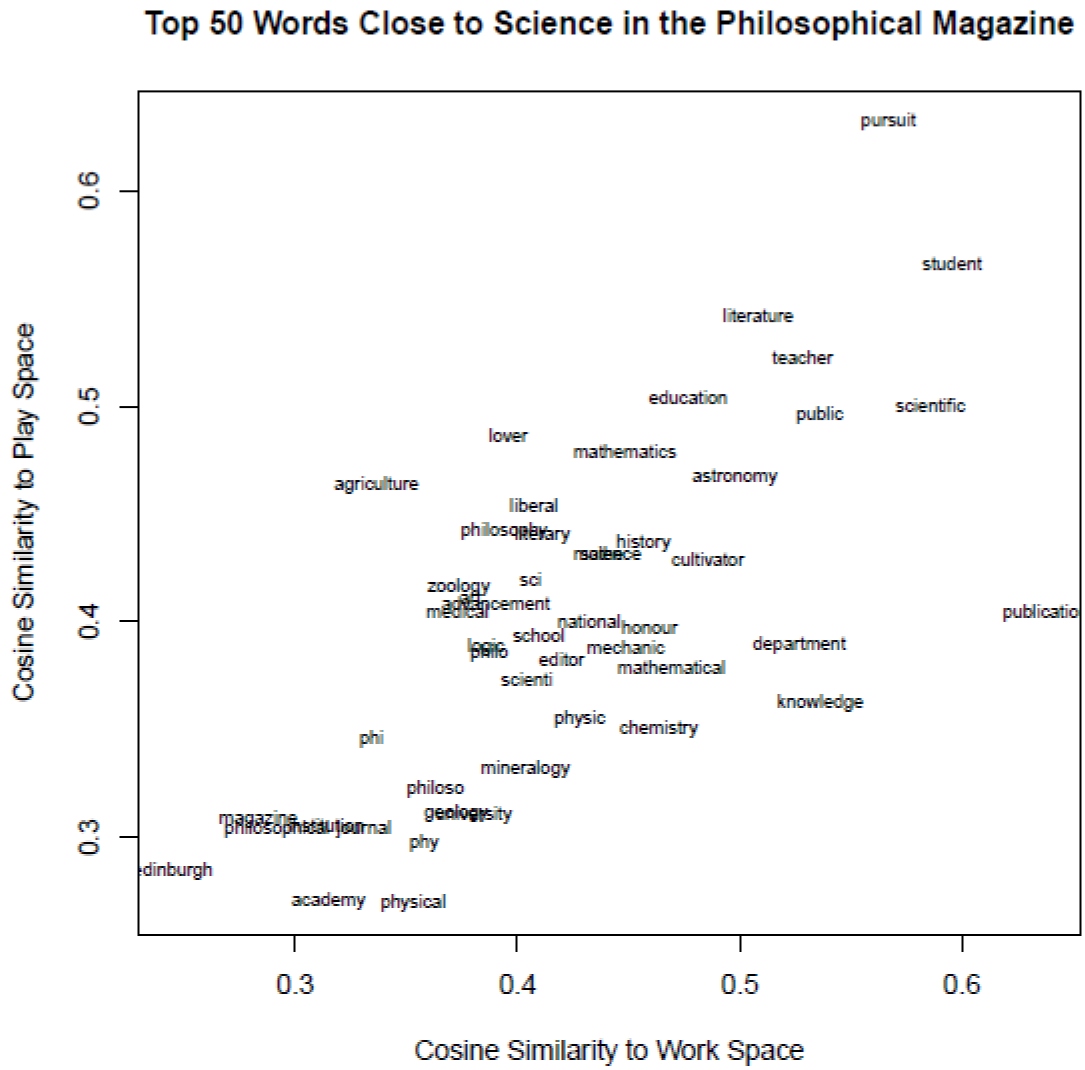

Figure 1-1: Plot of words that are closest to *science* in the *Philosophical Magazine* based on their cosine similarity to the work space or the play space.

Plotting the top 50 words close to *science* in *Nature*, as in Figure 1-2, reveals that this vector space model has placed words associated with science closer to the work space. Whereas the words in Figure 1-1 were, for the most part, near the diagonal line between the work space and the play space, in the *Nature* vector space model, words associated with *science* are also generally closer to the work space. Again, there are some exceptions. *Public* is, interestingly, closer to the play space than it is to the work space. It is also interesting that this vector space model has placed terms associated with medicine equidistant from work and play. But most words associated with *science*, such as *science*, *scientific*, *knowledge*, or *engineer*, are closer to the work space than they are to the play space, suggesting a stronger connection between science and work than between science and play here.

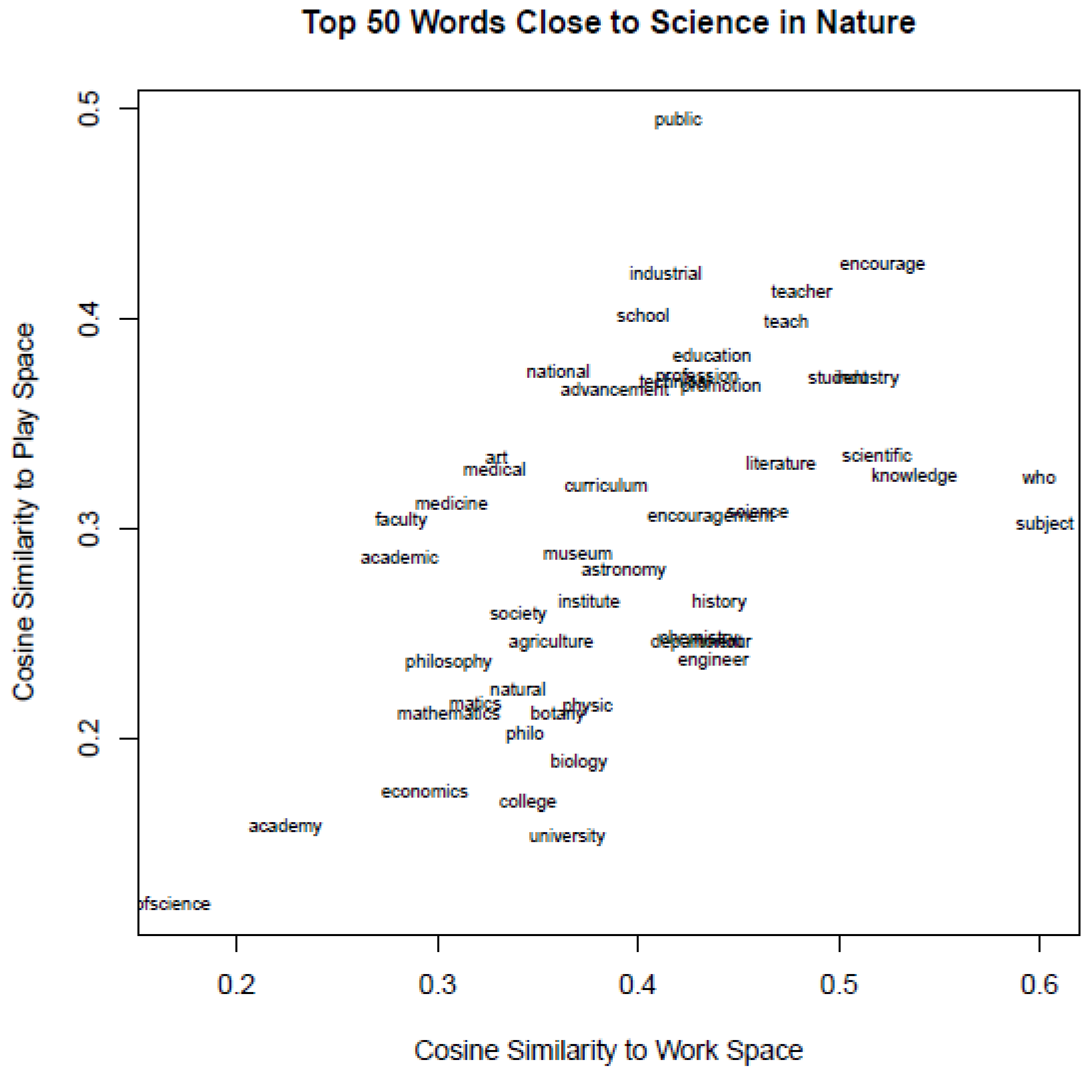

Figure 1-2: Plot of words that are closest to *science* in *Nature* based on their cosine similarity to the work space or the play space.

Figure 1-3 demonstrates that, in the scientific life writing vector space model, the words closely associated with *science* also tend to be more related to the work space than the play space. Again, there are some outliers. As in the *Philosophical Magazine* vector space model, *pursuit* is a word that is related to both the work space and the play space. But, when compared to the other corpora, this vector space model has a higher number of words that are far more related to work than to play. For example, *research* and *scientific* are much more strongly associated with work than with play.

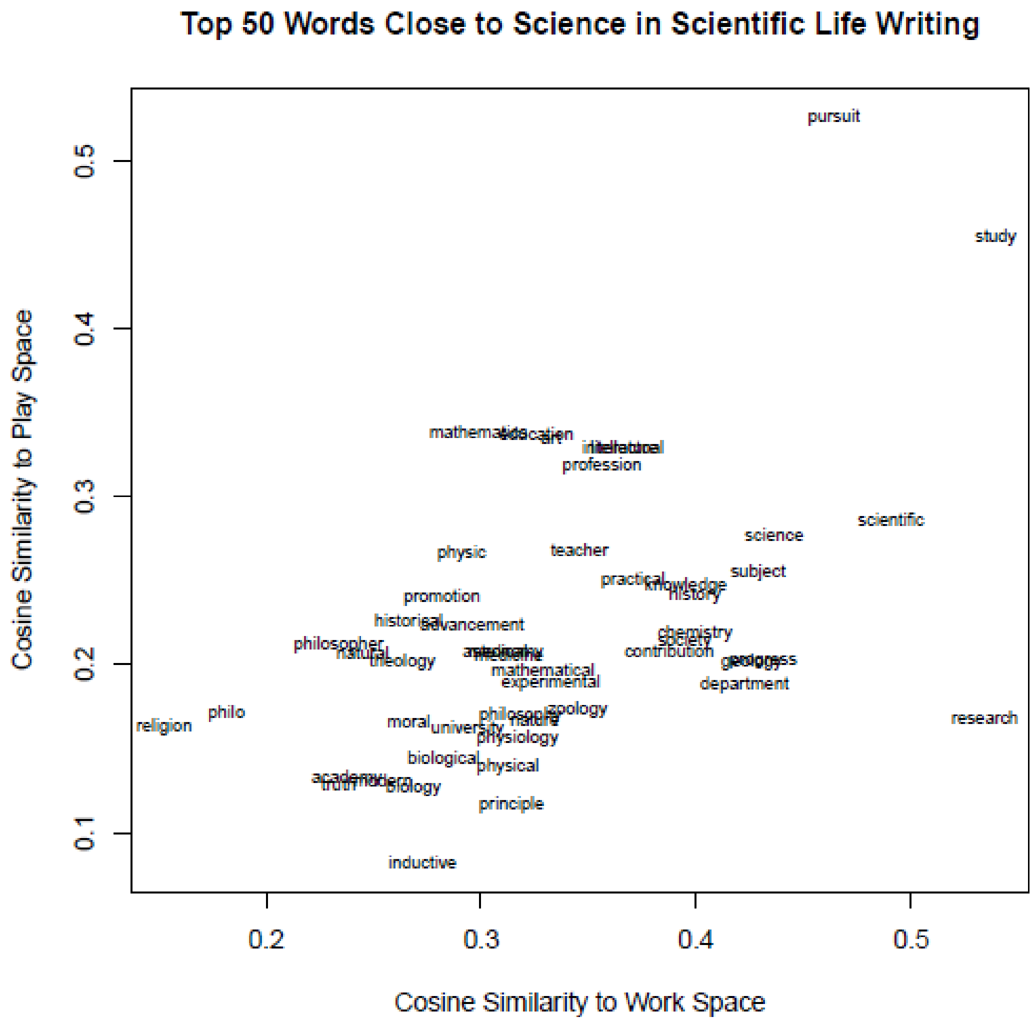

Figure 1-3: Plot of words that are closest to *science* in the scientific life writing corpus based on their cosine similarity to the work space or the play space.

The outlier among my vector space models is the corpus of popular science books aimed at children. In that model, *science* was actually a bit closer to the play space than it was to the work space. Plotting the words close to science, as I have done for the other vector space models, again helps explain why (Figure 1-4). The first thing to note is that in this vector space, the fifty words closest to *science* include several terms one might expect to be associated with play, such as *playbook*, *boy*, and *junior*. Unsurprisingly, all of these are closer to the play space than the work space. The word *scientific* is also very closely associated with the play space. This may be because some of the texts in this corpus include the phrases “scientific recreation” or “scientific amusement” in their titles. But, as in the other three vector spaces, *knowledge* here is still slightly more related to work than to play. This suggests that even in the popular science vector space, the idea of scientific knowledge might still be tied more to the idea of work.

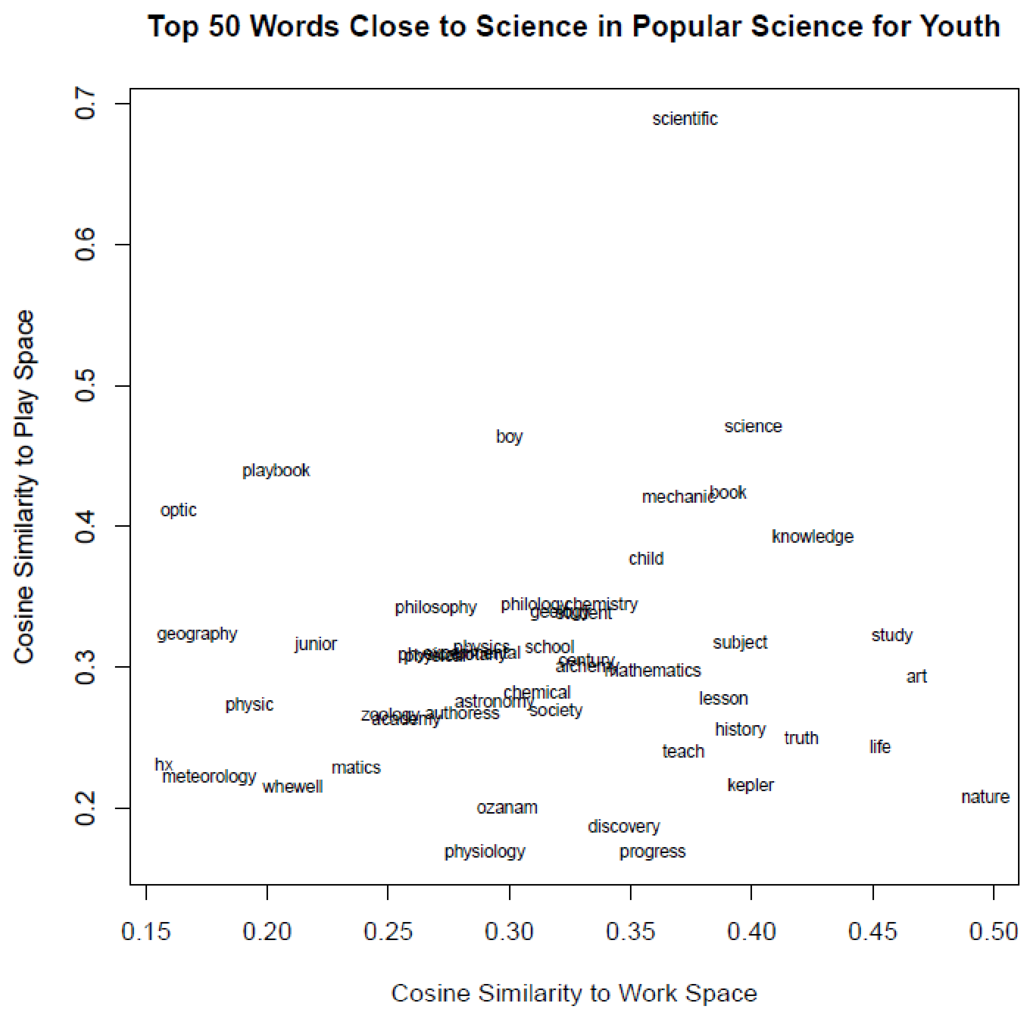

Figure 1-4: Plot of words that are closest to *science* in the set of popular science books aimed at youth, based on their cosine similarity to the work space or the play space.

While this project went through multiple iterations to make it as accurate as possible in the time available, there are certainly many ways in which it could be improved. For example, the corpora might be fleshed out more fully. Despite the work I put into compiling my juvenile popular science corpus and scientific life writing corpus, many texts have certainly been left out. Aileen Fyfe has estimated that around 30 or 40 children's science books were being published each decade early in the century, and that the number had risen to around 90 per decade after mid-century.[33] In compiling my popular science corpus, I was able to locate digitized versions of only a fraction of this number. In addition, the texts I did find almost certainly contain several errors that arose from the digitization process, which could be fixed, if more time was available. The optical character recognition process through which texts are usually digitized is often imperfect. Line breaks within texts can also cause problems when the texts are digitized. For example, in Figure 1-3, one of the words plotted is *philo*. This was likely "philosophy" in the original texts but was divided by line breaks in some of its appearances.

Another complication is that comparing cosine similarities in a vector space model is not always meaningful. I mentioned in the Methods section that cosine similarities are measures of how much one vector has to do with another, and that there is a difference between two words being unrelated and two words being antonyms. Antonyms are very related to one another and tend to appear near one another in vector space. But if one looks at the terms with the lowest cosine similarity to some word, there will not be any meaningful connections. Further complicating this issue is that human beings are very bad at comparing how unrelated two concepts are.[34] Is *tiger* more unrelated to *lamp* than *tiger* is to *sun*? It is unclear how one would

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[33] Aileen Fyfe, "Tracts, Classics and Brands: Science for Children in the Nineteenth Century" in *Popular Children's Literature in Britain*, ed. Julia Briggs, Dennis Butts, and M. O. Grenby (Aldershot: Ashgate, 2008), 212.
[34] Jurafsky and Martin, *Speech and Language Processing*.

judge this. This implies that cosine similarity is not uniformly useful for determining how related words in a vector space model are. Cosine similarity may be very valuable for determining whether two terms are related at higher cosine values. It may be less valuable near mid-range cosine similarity values. And it may be useless at very low cosine similarity values.

To determine whether the cosine similarities in the Results section are meaningful, I looked at the highest cosine similarities near the embeddings I was interested in. Typically, the words closest to terms like *labor* or *science* had cosine similarities between 0.5 and 0.7. For example, in the *Philosophical Magazine* vector space model, the word closest to *labor*, which is *industry*, has a cosine similarity of 0.667. However, there were some examples in which the closest words had lower cosine similarities. In that same vector space model, the word closest to *recreation*, which is *delight*, has a cosine similarity of only 0.489. In determining whether cosine similarities suggested a meaningful connection, I therefore chose a floor of 0.4. So I feel confident asserting that because *science* had a cosine similarity of 0.436279 with the work space, and only 0.277404 with the play space in the scientific life writing corpus, that *science* is in fact more related to the work space than the play space within that vector space model. But I would feel significantly less certain comparing a cosine similarity of 0.27 to 0.26.

The size of the training set also plays an important role in determining how accurate the word embedding is. The first time word2vec makes a vector space, it puts all the words in random places, and then tests to see how accurate they are over the iterations. It needs to see many examples of a word in its context to know that it should "nudge" the word towards related words. As I noted in the Methods section, in word2vec, two models are possible: skip-gram and continuous-bag-of-words (CBOW). Skip-gram tends to work better with smaller amounts of training data and is less likely to overfit frequently used words. This means that it can place rarer words more accurately in the vector space. CBOW is slightly more accurate for more frequent words and is the faster process. In my corpora, the words "recreation" and "amusement" tend to occur less frequently than "labor" and "work." For example, in the *Philosophical Magazine*, "recreation" made up, on average, 9.2E-5% of the words in a decade, while "work" made up, on average, 6.8E-2%. Because "work" appears in the corpus much more frequently than "recreation," Word2vec had far more opportunities to nudge it towards words that were related to it. The placement of the work space may be less random than the placement of the play space.

While I did decide that a skip-gram approach was more accurate for these vector space models, I also created CBOW models for comparison. The cosine similarities found in these CBOW models are shared in Table 1-2, below. There are some crucial differences in this CBOW model. First, most of the cosine similarities are lower: as I just discussed, this does make it more difficult to determine whether one can meaningfully compare these values. The other notable difference is that in this vector space model, work is more related to science than play is in the popular science corpus. While I have decided that the skip-gram vector space models are the more reliable representation of the corpora, it is important to keep in mind that these vector space models are just that: models representing the texts. These are mathematical transformations which aim to show qualities of a collection of texts that might not have been seen before. And in the skip-gram vector space models, what is demonstrated is that popular science books aimed at children are the only type of scientific writing analyzed in which science is more connected to play than work.

Corpus	Popular Science Books for Youth	*Philosophical Magazine*	*Nature*	Scientific Life Writing
Cosine Similarity between Work Space and S*cience*	0.293757	0.277273	0.246627	0.32228
Cosine Similarity between Play Space and *Science*	0.237414	0.269021	0.184848	0.126861
Difference	0.056343	0.008253	0.061779	0.195418

Table 1-2: Cosine similarities between work space and *science* and play space and *science*, in the CBOW vector space models.

VI. Conclusion

For this project, I constructed four corpuses of nineteenth-century British science writing: a collection of popular science books for young readers, the collected volumes of the *Philosophical Magazine* and the volumes of *Nature* published in the nineteenth century, and a collection of scientific life writing books. I created word2vec vector space models of each of these corpuses to determine whether science was more related to work or play in each. To determine the part of the vector space model associated with play, which I called the play space, I averaged the embeddings for *recreation* and *amusement*. To determine the part of the vector space model associated with work, I averaged the embeddings for *labor* and *work*. Cosine similarities demonstrated that in this model, work was more related to science than play was in three of the four corpora. The one exception was the corpus of popular science books aimed at young readers. This is what one might expect, given the strong association between childhood and play.

These vector space models could be improved. Future work might create more models for each corpus, to compare how much of an impact the randomization involved in word2vec is having. Texts within the corpora could be more rigorously cleaned. But these results do suggest that to understand the values of playfulness to science, an analysis of nineteenth-century popular science would be a good place to start. In the next chapter, I will analyze one particularly playful example from my popular science corpus: John Ayrton Paris's *Philosophy in Sport Made Science in Earnest* (1827).

Chapter 2 - The Profits of Play in John Ayrton Paris's *Philosophy in Sport*

I. Introduction

As I demonstrated in Chapter One, play was more associated with science than work was in nineteenth-century popular science books aimed at youth. This is almost certainly because texts which aimed to blend amusement and scientific instruction, often referred to as "rational recreation," became popular in the late eighteenth century[1] and continued to enjoy popularity in the nineteenth.[2] While professional scientific practitioners were increasingly labelling themselves "scientific workers,"[3] many late-eighteenth and nineteenth-century popular science texts seemed to go out of their way to remind readers that science could be a form of play.

One of the most frequently referenced rational recreation texts was John Ayrton Paris's *Philosophy in Sport Made Science in Earnest* (1827), hereafter referred to as *Philosophy in Sport*. Paris, a physician who researched natural philosophy, chemistry, and geology, made his reputation on the academic and commercial success of his *Pharmacologia, or the History of Medicinal Substances* (1812).[4] But it was his popular science text—and in particular its presentation of a new optical toy, the thaumatrope—which cemented his legacy. [5] When his colleague William Munk wrote a memoir of Paris's life in 1857, he described *Philosophy in*

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[1] Aileen Fyfe, "Tracts, Classics and Brands: Science for Children in the Nineteenth Century" in *Popular Children's Literature in Britain*, ed. Julia Briggs, Dennis Butts, and M. O. Grenby (Aldershot: Ashgate, 2008), 211.
[2] Fyfe, "Tracts, Classics and Brands," 212.
[3] Ruth Barton, "'Men of Science': Language, Identity, and Professionalization in the Mid-Victorian Scientific Community," *History of Science* 41 (2003): 87.
[4] William Munk, *A Memoir of the Life and Writings of John Ayrton Paris* (London: Bell and Daldy, 1857), 24.
[5] It should be noted that Charles Babbage claimed that Paris was not the original inventor, but that histories of optical technologies typically cite Paris as the origin.

Sport as "too well known to require more than a passing notice" due to its "enormous popularity."[6] When a writer for the *Liverpool Mercury* in 1867 sought to describe the entertainment of a séance, the phrase they had on hand was "Philosophy in Sport Made Science in Earnest."[7] When another writer marveled in the *Western Mail* about the toys available in London in the 1870s, the point of reference was, again, Paris's text.[8] *Philosophy in Sport* went through numerous editions, some legitimate and others plagiarized under other titles.[9] However, despite a recent increase in scholarly work on the too often ignored genre of popular science texts,[10] *Philosophy in Sport* has drawn little attention. Most work on *Philosophy in Sport Made Science in Earnest* has either tangentially mentioned the text[11] or focused only on its presentation of the thaumatrope.[12]

Given its popularity, this chapter takes *Philosophy in Sport* as a case study for understanding the functions of playful science. Paris tells the story of the Seymour family and the various lectures that Mr. Seymour delivers that use toys such as marbles, hoops, kites, and tops to teach his children -- primarily his son Tom -- science. By focusing on the mechanisms of these toys, Paris provides not only instruction on science, but also on history, through the figure of the obstinate vicar and antiquarian Peter Twaddleton, whose hatred of puns and suspicion of teaching science through play is gradually overcome by the efficacy of Mr. Seymour's lessons.

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[6] Munk, *Memoir of the Life and Writings of John Ayrton Paris*, 29-30.
[7] "Philosophy in Sport Made Science in Earnest," *Liverpool Mercury*, no. 6141 (3 October 1867).
[8] "London," *Western Mail*, no. 235 (29 January 1870).
[9] See *Boy's Own Book; Complete Encyclopedia of Athletic, Scientific, Outdoor and Indoor Sports* (New York: T.R. Knox, 1884); *Sports and Amusements for the Juvenile Philosopher: A Present for the Young* (Middletown, Conn.: E. Hunt, 1836).
[10] For more on the history of work on popular science, see James Secord, "Newton in the Nursery: Tom Telescope and the Philosophy of Tops and Balls, 1761-1838," in *Science in the Nursery: The Popularisation of Science in Britain and France, 1761-1901* (Newcastle: Cambridge Scholars Publishing, 2011); Aileen Fyfe and Bernard Lightman, "Science in the Marketplace: An Introduction," in *Science in the Marketplace: Nineteenth-Century Sites and Experiences*, ed. Aileen Fyfe and Bernard Lightman (Chicago: University of Chicago Press, 2007).
[11] See, for example, Daniel Brown, *Poetry of Victorian Scientists: Style, Science, and Nonsense* (Cambridge: Cambridge University Press, 2015); Melanie Keene, "Familiar Science in Nineteenth-Century Britain," *History of Science* 52, no. 1 (2014).
[12] See, for example, Nicholas J. Wade and Dieter Heller, "Scopes of Perception: The Experimental Manipulation of Space and Time," *Psychological Research* 60, no. 4 (1997).

The uncertain profitability of play is a central theme in *Philosophy in Sport*. The text returns again and again to the question of the profits of a philosophy in sport for Paris, for readers, and for the characters of the text. The question of profit is raised at the start of each volume, where an excerpt from William Cowper's poem *Tirocinium, or, A Review of Schools* (1784) serves as the epigraph. Cowper promises that by directly guiding their charge, fathers can levy "A tax of profit from his [the child's] very play."[13] Exactly what "value" will be gained from this tax is left unspecified.

In this chapter, I draw attention to three "profits" Paris earns through blending play and science: it encourages his readers to craft toys that let them see things they could not see before, it allows him to include absurdities that promote readers' engagement, and it provides a model for how children might develop into scientific practitioners as adults. All three of these functions will reappear in later chapters, in the discussion about writing aimed at adult scientific practitioners.

II. Crafting Opportunities to See

One benefit of play, in *Philosophy in Sport*, is promised by the names of the central characters: Mr. Seymour teaches his children to 'see more' by explaining scientific phenomena through toys. This is an idea that Paris might have taken from Cowper, who argues that the key to wringing profit from the child's play is for the father to teach the schoolboy a new way of looking at the world. Cowper encourages a father:

> To lead his son, for prospects of delight
> To some not steep, though philosophic, height,
> Thence to exhibit to his wond'ring eyes

[13] John Ayrton Paris, *Philosophy in Sport Made Science in Earnest; Being an Attempt to Illustrate the First Principles of Natural Philosophy by the Aid of Popular Toys and Sports*, 3 vols. (London: Longman, Rees, Orme, Brown, and Green, 1827).

> Yon circling worlds, their distance, and their size
> …
> To show him in an insect or a flow'r
> Such microscopic proof of skill and pow'r.[14]

Mr. Seymour, in *Philosophy in Sport*, follows this advice, teaching Tom to see the scientific phenomena that underlie the motions of various toys and sports apparatus. By the end of *Philosophy in Sport*, Tom Seymour has learned his lessons about how one can find science in play and toys so well that he now attempts to penetrate every type of amusement with his scientific gaze. For instance, while watching "exhibitions of vaulting, tumbling, balancing, and rope-dancing" at a festival, he takes it upon himself to "attentively follow… every change of position" and to explain "the philosophical principles upon which each of the tricks might be supposed to depend."[15] Tom's habit of deconstructing the method and worth of every form of entertainment is presented in *Philosophy in Sport* as evidence of his scientific acumen.

The central innovation of *Philosophy in Sport*, Paris's thaumatrope, is a fitting symbol of play's ability to reveal the previously unseen. The thaumatrope (Figure 2-1), or "wonder-turner," was essentially just a circular card with an image on either side. As Paris describes, this nineteenth-century optical device was:

> founded upon the well-known optical principle, that an impression, made on the retina of the eye, lasts for a short interval, after the object which produced it has been withdrawn. During the rapid whirling of the card, the figures on each of its sides are presented with such quick transition that they both appear at the same instance, and thus occasion a very striking and magical effect. On each of these cards a device is introduced, with an appropriate motto, or epigram, the point of which is answered, or explained, by the change which the figure assumes during the rapid whirling of the card.[16]

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[14] William Cowper, *The Task, and Tirocinium* (Philadelphia: McCarty & Davis, 1821), 179.
[15] Paris, *Philosophy in Sport*, 3:72-73.
[16] Paris, *Philosophy in Sport*, 3:6.

For example, Figure 2-2 demonstrates the sort of “spurious wit” and “buffoonery” these thaumatropes provided.[17] When this thaumatrope is spun by pulling or twisting the string, persistence of vision creates the illusion that the rat on one side has been placed inside the cage on the other. The motto, “Why is this rat like an opposition member in the House of Commons, who joins the ministry?” is answered “because by *turning round* he gains a snug birth, but ceases to be free.”[18] In other words, this is a toy which teaches a lesson: that politicians who become ministers of the crown after an election may protect their positions, but that they become beholden to that party’s leaders. It is also a toy which literally teaches children that play can help them see hidden meanings.

Figure 2-1: Illustration of Tom and Louisa Seymour observing the local vicar, Mr. Twaddleton, spinning the thaumatrope, or “wonder-turner,” in Paris’s *Philosophy in Sport*.[19]

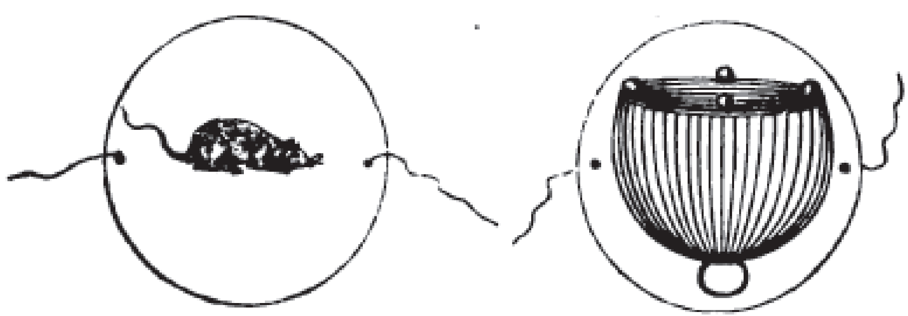

Figure 2-2: Illustration of the two sides of a thaumatrope in Paris’s *Philosophy in Sport*.[20]

[17] Paris, *Philosophy in Sport*, 3:10.
[18] Paris, *Philosophy in Sport*, 3:7-8.
[19] Paris, *Philosophy in Sport*, 3:1.
[20] Paris, *Philosophy in Sport*, 3:7-8.

In addition to being objects that teach readers to see what they previously could not, toys in *Philosophy in Sport* are objects that children were encouraged to craft themselves: in essence, designing their own experimental apparatus at home, in a time when there was a lack of scientific instruments in classrooms. [21] Paris does note that some of the toys referenced in his text could be bought. Mr. Seymour describes a few as having been purchased in Paris, and the thaumatrope itself can be obtained from publisher William Phillips in Lombard Street. Even though Paris warns readers against buying "those inferior imitations which are vended in the shops of London,"[22] the text implicitly encourages readers to build their own.

The purchased version is not the only version discussed in the text. Instead, when the thaumatrope first arrives, Mrs. Seymour begs "it might not be exhibited until she should have effected an improvement in its construction, of which she at once perceived it to be capable."[23] Her improvement is to add an outer framework, so that the disc not only spins, but now also rotates, allowing for rudimentary animation, as the relationship between the two images changes (Figure 2-3).

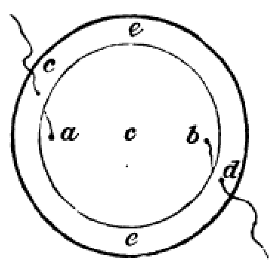

Figure 2-3: Illustration of the improvement made to the thaumatrope by Mrs. Seymour in Paris's *Philosophy in Sport*.[24]

[21] David Layton, *Science for the People: The Origins of the School Science Curriculum in England* (London: Allen and Unwin, 1973), 33.
[22] Paris, *Philosophy in Sport*, 3:2.
[23] Paris, *Philosophy in Sport*, 3:3.
[24] Paris, *Philosophy in Sport*, 3:23.

Mrs. Seymour's improvement of the thaumatrope is notable in part because it is one of many spaces in the text in which Paris challenges the gendering one might expect from rational recreation. The toys typically used in popular science texts—toys of motion, like tops—were frequently associated with boyhood (more on this in the next chapter). For instance, one of the "profits" of pursuing this method of education that Mr. Seymour suggests is that when Tom is done with the toys, they can be passed on to his brother John.[25] In this respect, it is not surprising that Tom Seymour is the main character, or that the father-son relationship is centered. However, the entire Seymour family ends up being involved in lessons. Even though Mr. Seymour initially invites Tom's sisters to participate with the somewhat dismissive idea that "Louisa and Fanny, who are of an age to understand the subject, will not prove uninterested spectators,"[26] Louisa ends up being central to the text, and proves just as apt as Tom both in her play and in her scientific understanding. Mrs. Seymour's quick apperception of the thaumatrope and its possibilities demonstrates that she also is more than an "uninterested spectator." Indeed, she has a quicker understanding of the scientific toy than Mr. Twaddleton, who exclaims with surprise on first seeing the thaumatrope's action that it is "magic!"[27]

In addition, despite Paris's explanation about why readers should buy the official product, Mrs. Seymour's improvements signal that Paris is open to readers making their own thaumatropes. In fact, by providing illustrations, Paris is essentially providing a template for readers to recreate the thaumatropes on their own. As Barbara Maria Stafford notes, all scientific illustrations in popular science books provide images to be constructed in the "teaching

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[25] Paris, *Philosophy in Sport*, 1:21.
[26] Paris, *Philosophy in Sport*, 1:21.
[27] Paris, *Philosophy in Sport*, 3:7.

laboratory of the home."[28] A reader could even make their thaumatrope by using the pages of *Philosophy in Sport* as materials. Thaumatropes are, after all, just discs of paper with illustrations on them. One could cut out the illustrations of the caged rat thaumatropes (Figure 2-2), paste the two sides together, and create their own thaumatrope with relatively little effort. As if to encourage readers to do so, Paris goes out of his way to draw attention to the volumes' materiality, describing his writing in terms of "plains of parchment" or "plains of foolscap."[29] When the Seymours' foolish neighbor Miss Ryland has her face dusted by a servant, her face becomes a "title-page" which must be cleaned, forcing readers to remember the materiality of the book in their hands.[30] And when Paris gives his instructions for making a kite, the waste paper Mr. Seymour has provided has come from other books like *Philosophy in Sport*. Paris jokes, in this part of the text, that books tend to end up being used in ways that match their original function. Mr. Seymour explains that he has seen Sir John Forbes work, titled *Original Cases*, sent to a trunk-maker, and has received a quantity of uric acid wrapped in Dr. Thomson's *Principles of Chemistry*.[31] He even claims to have seen one of John Ayrton Paris's previous works, his *Treatise on Diet*, being used to wrap a piece of fat bacon. And so the various papers that the Seymours use to build their kite tail consist of works on "retail," "entail," etc. [32] Reading through this section of the text encourages readers to reflect on what might become of the book in their hands. If a book's ultimate fate matches its content, surely *Philosophy in Sport* is destined to become a toy such as a thaumatrope itself. And, as if to push readers hesitating to cut into their own books, Paris introduces the illustration or the rat and cage thaumatrope by

[28] Barbara Maria Stafford, *Artful Science: Enlightenment Entertainment and the Eclipse of Visual Education* (Cambridge, MA: MIT Press, 1994), 58.
[29] Paris, *Philosophy in Sport*, 1:315, 2:247-48.
[30] Paris, *Philosophy in Sport*, 1:304.
[31] Paris, *Philosophy in Sport*, 2:84.
[32] Paris, *Philosophy in Sport*, 2:87.

insulting the reader, explaining that he provides the illustration out of fear "that some of our readers may be as dull of comprehension as the vicar."[33]

I saw only one way to test this possibility. Figure 2-4 is a picture of a thaumatrope that I made, using the pages of a nineteenth-century edition of Paris's *Philosophy in Sport*. This thaumatrope was not made from an original edition of Paris's work. This version was published in 1878 in New York by James Miller. Although some changes have been made to the plot and some experiments updated, this version does still include the template of the rat in the cage from the original (Figure 2-2). I found that I could indeed create a thaumatrope by simply cutting out the images provided and pasting them opposite one another. To create a longer lasting thaumatrope, I glued these images onto a plastic disk, but I have verified that a more temporary version can be created simply by gluing the pieces of paper together. I can verify that playing with this thaumatrope is, indeed, pretty fun, and is a neat illustration of persistence of vision. If you, reader, have printed out this dissertation, you could do the same. Simply cut out the images in Figure 2-2, paste them together (preferably on cardboard or a thicker card stock paper) and you will have your own thaumatrope.

Figure 2-4: Picture of a thaumatrope created by cutting images out of Paris's *Philosophy in Sport* (New York: James Miller, 1878).

[33] Paris, *Philosophy in Sport*, 3:7.

The text also makes clear that if one did purchase a thaumatrope, they could still make it their own by creating their own mottos for the images. Thaumatropes could have multiple meanings. For instance, one thaumatrope in the text shows a watch-box on one side, and a watchman sleeping at his post on the other. Mr. Twaddleton suggests a political moral: "like most worthies who gain a post, by *turning round*, he sleeps over his duty."[34] The actual motto, however, concerns laziness rather than politics:

> The caprice of this watchman surpasses all bounds;
> He ne'er sits in his box, but when going his *rounds*:
> While he no sooner rests, 'tis a strange paradox!
> Then he flies from his post, and *turns* out of his box.

In acknowledging that the images in his thaumatropes might have various morals applied, Paris again seems to be encouraging readers to make the thaumatrope their own. In fact, some of these morals contain such egregious puns that one suspects Paris is encouraging his audience to attempt better ones.

The design of thaumatropes makes it especially apparent, in *Philosophy in Sport*, that children and their parents can build these toys for themselves. However, Paris also signals that readers may be able to craft many of the other toys mentioned in the text. Paris claims that his is the first work to ever give "clear directions for constructing a kite," which clearly suggests that the reader is meant to follow the directions if possible.[35] In other cases, Paris provides enough information about how a toy was created that readers should be able to make their own version. For example, Mr. Seymour gives Tom toy Prussian soldiers with curved bottoms that always right themselves when knocked over (Figure 2-5). These soldiers allow Mr. Seymour to help

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[34] Paris, *Philosophy in Sport*, 3:9.
[35] Paris, *Philosophy in Sport*, 2:78.

Tom visualize the concept of center of gravity. But even though Mr. Seymour explains that these are Parisian toys, he also carefully explains that "the figure… is made of the pith of the elder tree, which is extremely light, and is affixed to the half of a leaden bullet."[36] This tells readers that if they have a lightweight wood and a half-bullet, they could make their own version. Moreover, the fun the Seymours have with these toys helps to convince readers that they *should* craft these toys, building instruments that children can enjoy but which also help them see and understand natural phenomena they might otherwise have missed.

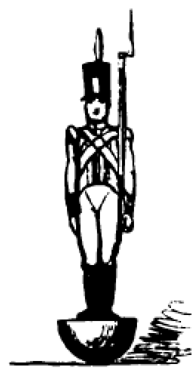

Figure 2-5: "Prussians" that right themselves when knocked over in Paris's *Philosophy in Sport*.[37]

III. Engagement through Playful Absurdity

Another place where the theme of profitability appears in *Philosophy in Sport* is in Paris's use of fiction. Paris begins volume I with an acknowledgement of Maria Edgeworth, whose *Harry and Lucy* (1813) shows, according to Paris, "how profitably, and agreeably, the machinery of fiction may be worked for the dissemination of truth."[38] Paris makes use of fiction in *Philosophy in Sport* as well, although only half of the narrative is taken up by the imagined scenes in which a father teaches his children science in a domestic setting. Popular science books in which

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[36] Paris, *Philosophy in Sport*, 1:253.
[37] Paris, *Philosophy in Sport*, 1:253.
[38] Paris, *Philosophy in Sport*, 1:vi.

lecturers taught children was nothing new. This was the strategy even in John Newbery's *The Newtonian System of Philosophy* (1761), the text which is often said to had launched the children's literature market. But the other half of *Philosophy in Sport*, which is almost always ignored by scholarship, unravels the mysterious connections between three newcomers to the village of Overton. First there is Mr. Richdale, a reclusive young man with a mysterious past who moved to the area a few months before the start of the narrative. An even more recent arrival is Major Snapwell, a wealthy bachelor. After his nephew and intended heir Henry Beacham died in a shipwreck, soon followed by Henry's distraught fiancée, Major Snapwell began to travel the world, entrusting the management of his money to his friend Wilcox. And finally, there is Isabella Villers, a visiting friend of Mrs. Seymour's who somehow knew Henry Beacham. The truth is eventually revealed after Isabella hears an echo of Richdale whispering her name in a rocky glen. It turns out, of course, that Richdale is Beacham. After Beacham's shipwreck, Wilcox lied to all three parties. He told Snapwell that Henry and Isabella were both dead. He told Isabella that Henry was dead, and that Snapwell blamed her for his death. And he told Henry that Isabella had died, that his uncle, thinking he was dead, was travelling the continent, and that Henry should wait a while, incognito, to avoid being pressured into marriage with a different woman. Wilcox escapes, but Henry and Isabella are married and celebrate a festival with the residents of Overton.

According to Paris, these romantic elements were one of his primary innovations in *Philosophy in Sport*: "I have exercised my fancy with a freedom and latitude, for which, probably, there is not any precedent in a scientific work. I have even ventured so far to deviate from the beaten track as to skirmish upon the frontiers of the Novelist, and to bring off captive some of the artillery of romance."[39] What exactly does Paris find profitable about teaching science alongside fictions like these? I argue that these fictions allow Paris to capture readers' attention, but perhaps not in the way one might expect. The absurd mishmash of genres allows Paris an opportunity to play a kind of game with the reader, within the text: a game that encourages readers to reread and replay scenes from *Philosophy in Sport*.

What Paris terms the novelistic elements of *Philosophy in Sport* are absurd, both in the sense that they are amusing and in the sense relating to the word's etymological origin in *absurdus*: they are *discordant*, sandwiched between Mr. Seymour's lectures in a way that distracts both from the lectures and from the romance plot.[40] For example, readers first learn about Richdale between two lectures that Mr. Seymour gives his children about Newton's three laws of motion. And at the dramatic moment when echoes bring together Henry and Isabella, readers may still be thinking about Mr. Seymour's explanation of how echoes work from earlier in the chapter. For some readers, the romance plot did go too far. For example, one writer for the *London Review*, discussing books for scientific instruction published in the 1860s, listed *Philosophy in Sport* as an example of an "absurd attempt… to mix up play with work, and to administer doses of science or philosophy under the guise of an amusing story."[41] Some later versions of *Philosophy in Sport*, published without Paris's name attached, excised the romance from the story. For example, *Sports and Amusements for the Juvenile Philosopher*, published in Connecticut by Edwin Hunt in 1836, keeps much of the dialogue from the Seymours (unwisely changed to the "Somers" family, removing the pun), but removes the other half of the plot

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[39] Paris, *Philosophy in Sport*, 1:xiii.
[40] ""absurd, adj. and n."," *OED*, https://www.oed.com/viewdictionaryentry/Entry/792.
[41] "Importance of Children's Literature," *Eclectic Magazine of Foreign Literature* 50, no. 1 (1860): 38.

entirely. A version of *Philosophy in Sport* included in the *Boy's Own Book*, published by Thomas Knox in New York in 1884, does the same.

In *Chance and the Eighteenth-Century Novel* (2010), Jesse Molesworth argues that "narratives [produce play through] the skillful orchestration of plot, the artful construction of character, and, equally important, the reader's role in ratifying each narrative 'move.'"[42] But in *Philosophy in Sport*, Paris invites readers to partake in a different kind of play. He goes out of his way to encourage readers to question whether they *should* ratify these absurd narrative moves, by drawing attention to how *unskillful* his orchestration of plot is. For example, Isabella does not appear until the midpoint of the text. Rather than trying to hide this clumsy plotting, Paris draws attention to it, as though daring readers to criticize the choice: "yes, gentle reader, it was the heroine of our story! who, in defiance of every established principle of novel-writing, has, for reasons which the sequel may, perhaps, justify, been studiously concealed from your view, until the second volume has nearly numbered half its pages."[43] Paris then further refuses convention by refusing to describe Isabella. He argues that he should not have to, since this is an "instructive history" rather than a "romance."[44] He suggests that readers should be satisfied by "the outline which your imagination must have already sketched."[45] And he suggests that there are so many other romances that all the good descriptions have already been taken: "the regions of fancy have been so despoiled of their blossoms, that scarcely a flower can be culled by him who would entwine a garland for the brow of his heroine."[46] The joke is that he is rejecting romantic description using the same flowery language that the stereotypical romances he is describing

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[42] Jesse Molesworth, *Chance and the Eighteenth-Century Novel: Realism, Probability, Magic* (Cambridge: Cambridge University Press, 2010), 134.
[43] Paris, *Philosophy in Sport*, 2:149.
[44] Paris, *Philosophy in Sport*, 2:150.
[45] Paris, *Philosophy in Sport*, 2:150.
[46] Paris, *Philosophy in Sport*, 2:150.

might use. Where Paris does stick to convention, he draws attention to his lack of originality. When it is revealed that Isabella was Henry Beacham's former lover, Paris notes that "those accustomed to the machinery of romance will probably have anticipated" the plot point.[47]

To ensure the reader is reflecting on whether they want to accept these writing choices, Paris has his publishers come into the tale in volume 2 to insult them. Towards the end of that volume, right after Wilcox's scheme is revealed, the narrator offers "an apology for the abrupt and rapid manner in which we shall now accelerate our narrative."[48] Rather than explaining the immediate fallout of the revelation, the narrator asks the reader to sleep until the morning of the wedding day. After some ellipses representing the readers' sleep, the narrator urges the reader to wake once again, and begins to explain what is happening on the morning of the marriage. But "while [the reader and narrator] are thus talking" about the morning preparations, the marriage ceremony ends. The narrator is about to describe the banquet after the wedding, "when [their] publishers, like harpies, unexpectedly pounced… and warned [them] from the feast."[49] The publishers tell the writer that the volume is already too long and argue that readers do not really care about narrative resolution: "as long as you get them off the stage, I'll answer for it the *reader* wo'n't [sic] care how."[50] It is up to the readers to determine whether or not they agree with this somewhat insulting assumption.

I am arguing that rather than discouraging readers, the absurdity of Paris's mishmash of genres and these unconventional writing choices encourage more engagement. If *Philosophy in Sport* had only included Mr. Seymour's lectures, readers might become bored. There would be

[47] Paris, *Philosophy in Sport*, 2:237.
[48] Paris, *Philosophy in Sport*, 2:312.
[49] Paris, *Philosophy in Sport*, 2:314.
[50] Paris, *Philosophy in Sport*, 2:314.

little driving them to finish the book. But ironically, if *Philosophy in Sport*'s romance plot was too engaging, it might encourage readers to only focus on those elements, skipping over the lectures. Instead, *Philosophy in Sport* is designed in such a way that readers are encouraged to focus on both, because they are constantly being encouraged to reflect on whether they feel these pieces fit together or not.

IV. Shaping the Development of Scientific Practitioners

So far, this chapter has focused on immediate profits of play: however, *Philosophy in Sport* makes clear that Paris was critical of "penurious philosophers, whose ideas of utility are circumscribed within the narrow limits of direct and immediate profit."[51] Instead, the preface to *Philosophy in Sport* suggests that the blending of play and science was an investment that would be recouped later. As Paris puts it: "Youth is naturally addicted to amusement, and in this item his expenditure too often exceeds his allotted income. I have, therefore, taken the liberty to draw a draft upon Philosophy, with the full assurance that it will be gratefully repaid, with compound interest, ten years after date."[52] The "compound interest" Paris hopes to recoup here is an increased interest in science, as his goal is to foster "that early love of science which can never be derived from sterner productions."[53] In other words, play shapes the development of scientific practitioners.

The view that rational recreation could help shape children into responsible adults was not unusual. As Aileen Fyfe has noted, books for children were explicitly intended to mold the future of society: particularly the moral system that children would take up and enforce.

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[51] Paris, *Philosophy in Sport*, 1:219.
[52] Paris, *Philosophy in Sport*, 1:ix.
[53] Paris, *Philosophy in Sport*, 1:ix.

However, Fyfe also notes that the goal was not necessarily to encourage readers to take up the sciences as a profession. Few readers would have had opportunity to use their scientific knowledge as physicians or men of science. Instead, Fyfe argues that most readers were more likely to grow into women or non-professional men who might continue to practice, as recreations, sciences that did not require expensive equipment or a formal education.[54]

Paris does not specify what Tom Seymour might do with the scientific knowledge he gained through his recreations, as an adult. However, given that Paris cites Cowper at the beginning of each volume, one might expect that, as Cowper's *The Task* suggests, *Philosophy in Sport*'s goal is to "set some living worthy in [the schoolboy's] view, / Whose fair example may at once inspire / A wish to copy what he must admire."[55] In other words, it seems most likely that Tom's scientific recreations as a boy are meant to help him grow into a man like his father.

The text is somewhat vague about whether Mr. Seymour worked to discover or develop any new scientific knowledge, or whether he simply enjoyed learning about it. The narrator goes out of his way to specify that he will not be revealing the nature of the business Mr. Seymour is usually occupied with.[56] The text does say that his business involves "works, books, and drawings."[57] He is also landed gentry, so at the very least, he is not working as a professional scientific practitioner to support his family's livelihood. But readers are informed that Mr. Seymour studied in Germany under geologist Abraham Gottlob Werner;[58] that he built a temple dedicated to Werner on his property, depicting various geological strata;[59] that he is familiar with

[54] Fyfe, "Young Readers and the Sciences" in *Books and the Sciences in History*, ed. Marina Frasca-Spada and Nicholas Jardine (Cambridge: Cambridge University Press, 2000), 283.
[55] Cowper, *The Task, and Tirocinium*, 179.
[56] Paris, *Philosophy in Sport*, 1:143.
[57] Paris, *Philosophy in Sport*, 1:24.
[58] Paris, *Philosophy in Sport*, 1: 10.
[59] Paris, *Philosophy in Sport*, 1:8.

the "scientific circles of London";[60] and has attended meetings of the Geological Society of London.[61] All of this suggests that Mr. Seymour might be labelled as a "man of science" or "scientific worker" in nineteenth-century Britain. In *Philosophy in Sport*, then, the eventual profit is that Tom Seymour will become so interested in science that he will follow his father in participating in the scientific community. And by following Tom's example, child readers might also develop into scientific workers.

V. Conclusion

Popular science is a complex site at which the interests of scientists, educators, the clergy, parents, children, publishers, toy manufacturers, and scientific showmen all converged. As one might expect, given these multiple and sometimes competing interests, play could serve multiple functions; or, as Paris might have put it, play had various possible profits in popular science works. In this chapter, I have drawn attention to three benefits of play in Paris's *Philosophy in Sport*. First, Paris uses playfulness to encourage readers to craft toys that let them "see more." Second, playful absurdities in the narrative promote readers' engagement. And third, playfulness becomes part of Paris's model for how a child like Tom might develop into an adult scientific practitioner.

There are, doubtless, other benefits to play in Paris's work. For example, I have not discussed the "profits" that Paris himself gained by approaching scientific instruction through play. This was a decision that probably helped to sell the book itself, as well as the thaumatrope it advertised. Another profit is certainly the pleasure that Paris received while writing the text.

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[60] Paris, *Philosophy in Sport*, 3:2.
[61] Paris, *Philosophy in Sport*, 1:217.

The British medical scientific practitioner William Miller Ord, touching briefly on Paris's work in an 1894 lecture, suggests that Paris's text should be viewed as the sort of "hobby" which, when indulged, can provide a medical practitioner with "the truest rest," through "extensions of professional occupation into regions of pleasant diversion."[62]

Rather than attempting to find every possible profit of play in *Philosophy in Sport*, it seems wiser to take a lesson from Paris himself and learn that there is value in bringing a chapter to a swift (if unexpected) ending. Playful science served Paris quite well in *Philosophy in Sport*, allowing him to teach his child audience and set them on the path towards becoming adult scientific workers. However, I demonstrate in the chapters that follow that playful science could benefit even adult practitioners in these same ways.

[62] William Miller Ord, "An Oration: A Doctor's Holiday. Delivered at the Annual Conversazione of the Medical Society of London on May 21st, 1894," *The Lancet*, 26 May 1894, 1288.

Chapter 3 – Play and Experiments on Perception: James Clerk Maxwell and the Secret of the Top

I. Introduction

One Victorian who was familiar with Paris's *Philosophy in Sport* (but does not seem to have read it himself) was physicist James Clerk Maxwell.[1] Maxwell's own use of scientific recreations, his 'philosophy in sport,' would ultimately make him one of the most memorable examples of the play of Victorian scientific practitioners. As his biographer and friend William Garnett said, "to see Maxwell at his best was to see him at play. Few things could give more pleasure to the Professor of Physics in the University of Cambridge than a new toy, whether designed by himself or for anyone else […]; and to exhibit these toys to his friends at home in the evenings was a great delight."[2] In this chapter, I investigate how Maxwell was able to integrate this playfulness into his experiments, and to what ends.

Some measure of Maxwell's playfulness is illustrated by an anecdote which Garnett shared in Maxwell's obituary in *Nature*. Discussing objects Maxwell was donating to the Cavendish Laboratory, Garnett describes:

> the dynamical[3] top, whose moments of inertia[4] about three axes, which are at right angles to each other, can be so varied by means of screws that the axis of rotation can be made

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[1] James Clerk Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, ed. P. M. Harman (Cambridge: Cambridge University Press, 1990), 1:221.

[2] William Garnett, "Speech by William Garnett at the Maxwell Centennial Meeting," 1931, MS.Add.8385/10, James Clerk Maxwell: Correspondence and Papers, Cambridge University Library, Cambridge, U.K., 3.

[3] In this anecdote, 'dynamical' refers to the science of Dynamics, which Maxwell defined as "the science of the motion of matter as produced by known forces" (James Clerk Maxwell, "Inaugural Lecture at King's College, London. October 1860," in *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, ed. P. M. Harman (Cambridge: Cambridge University Press, 1990), 669).

[4] Moments of inertia can be thought of as an analog to mass: it is a measure of how much an object resists rotational acceleration about a particular axis.

> that of greatest or of least moment of inertia. […] When Prof. Maxwell came to Cambridge in 1857 to take his M.A. degree, he brought this top with him from Aberdeen. In the evening he showed it to a party of friends in college, who left the top spinning in his room. Next morning he espied one of these friends coming across the court, so jumping out of bed, he started the top anew, and retired between the sheets. The reader can well supply the rest of the story for himself. It is only necessary to add that the plot was completely successful.[5]

It is clear that Garnett believed this anecdote gave special insight into Maxwell, as it was repeated in *The Life of James Clerk Maxwell* (1882), written by Garnett and another friend of Maxwell's, Lewis Campbell.[6] A few years later, it reappeared in popularizer of science Robert Ball's *Star-Land* (1889).[7] Ball's recollection of "hearing a story" about the incident suggests that this anecdote may have been circulating not only in print but also orally among scientific practitioners.[8]

As with many accounts of playful science, the charm of the story seems to lie primarily in its incongruity. Maxwell takes a scientific instrument—a class of objects supposedly designed for disinterested discovery of truth—and finds pleasure in using it to suggest a falsehood. Garnett's account artfully suggests Maxwell's culpability, in its reference to a "plot," while refraining from suggesting that Maxwell actually verbalized a lie (the reader must "supply the rest of the story"). This ambiguity helps the dynamical top (Figure 3-1) to remain both an object for scientific work (a function also signaled by Garnett's careful description of the complicated working of the dynamical top's screws) and an object for play.[9]

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5 William Garnett, "James Clerk Maxwell, F. R. S.," *Nature* 21 (1879): 46.
6 Lewis Campbell and William Garnett, *The Life of James Clerk Maxwell* (London: Macmillan 1882), 499.
7 Robert Stalwell Ball, *Star-Land: Being Talks with Young People about the Wonders of the Heavens* (London: Cassell, 1889), 172.
8 Ball, *Star-Land*, 172.
9 Garnett, "James Clerk Maxwell, F. R. S.," 46; Ball, *Star-Land*, 172.

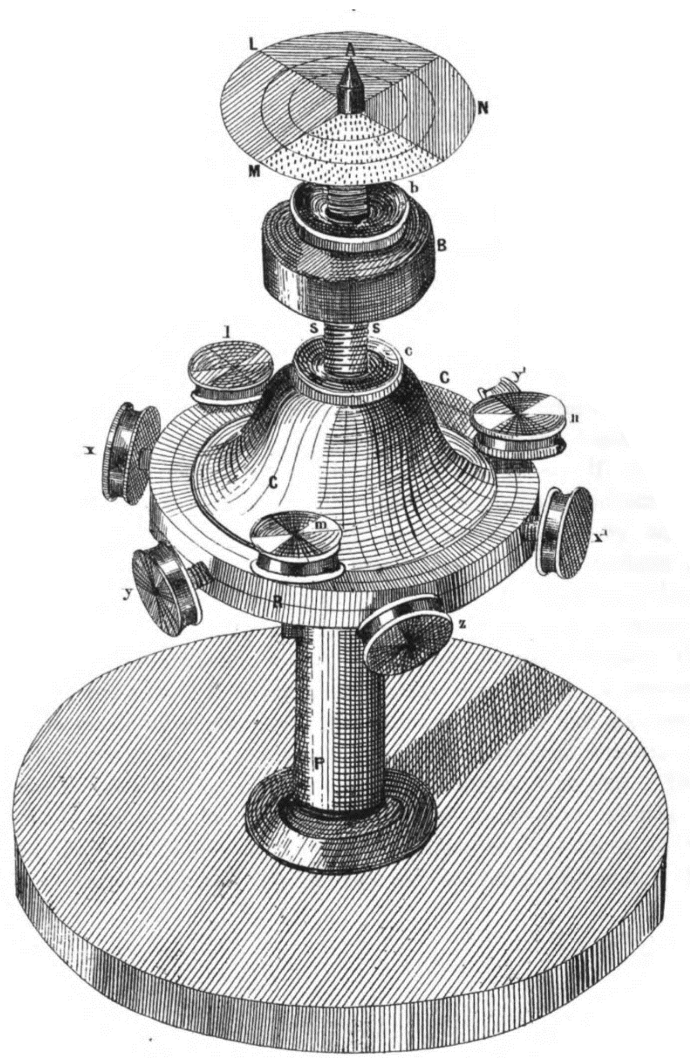

Figure 3-1: Maxwell's illustration of the dynamical top in "On a Dynamical Top" (1857)[10]

In *The Life of James Clerk Maxwell* (1882), Campbell and Garnett emphasize this ambiguity in a different way, by returning the top to its original context: Maxwell's desire to "illustrate dynamical propositions."[11] There, the anecdote ends somewhat differently. Rather than suggesting the reader construct an appropriate ending, Campbell and Garnett conclude the

[10] James Clerk Maxwell, "On a Dynamical Top, for Exhibiting the Phenomena of the Motion of a System of Invariable Form about a Fixed Point, with Some Suggestions as to the Earth's Motion," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press, 1890), 1:263.
[11] Campbell and Garnett, *Life of James Clerk Maxwell*, 499.

prank by describing how "the spinning power of the top commanded as great respect as its power of illustrating *Poinsot's Theorie Nouvelle de la Rotation des Corps*." Simply put, Poinsot's theory is a way of using geometry to visualize the rotation of a rigid object instead of algebraic calculations. In articulating a more specific ending, Campbell and Garnett therefore place the playful lie (the spinning power of the top) directly beside the scientific use of the top (illustration of Poinsot's theory), again emphasizing its dual functions.

To investigate the role of toys in Maxwell's scientific practice, this chapter analyzes Maxwell's descriptions of his dynamical and color tops in his scientific publications and correspondence. The central question is this: why did Maxwell choose to highlight their possible recreational uses by labeling these rotating objects as "tops"? In asking this question, I am not seeking out the psychological impetus behind Maxwell's playfulness. Since Campbell and Garnett's first biography, studies on Maxwell have sought to view Maxwell's adult scientific practice as the result of his childhood activities, through a process that Jordi Cat has referred to as a "cognitive series."[12] According to Cat:

> Maxwell's childhood experience and play with spinning toys such as a diabolo, curling stones and wheels of life instilled in him a preference and talent for exploring and using spinning systems, phenomena, concepts, and procedures: the spinning top, Saturn's rings, engines' governors, molecular vortices in the ether, spinning electrical flows and electric coils, the lenticular zoetrope, etc.

This is absolutely true. As I acknowledge below, Maxwell's color top bears some similarity to the tops he designed as a child for his own entertainment. However, it is not enough to merely note that Maxwell's enjoyment of tops as a child prompted his study of rotational motion. This alone does not explain why he chose to name later scientific instruments after the childhood toy.

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[12] Jordi Cat, *Maxwell, Sutton, and the Birth of Color Photography* (New York: Palgrave Macmillan), 28.

It is my contention that understanding this playfulness means seeking out the function of this label in Maxwell's work.

To understand how referring to these instruments as "tops" benefitted Maxwell's scientific practice, I shall focus on what Maxwell wrote about tops in his correspondence and scientific articles, relying on both archival and published resources. I begin by discussing how play with tops was understood in the nineteenth century and how Maxwell thought about play, before proceeding to investigate how these contexts help explain Maxwell's most well-known top—the 'color top.' I point out a rather practical effect of his choice to treat it as both an instrument of measurement and a toy: he was able to increase the number of observers for his experiments on vision and encourage readers to commission or build their own. In the final sections, I then investigate Maxwell's 'dynamical top' and argue that Maxwell also embraced the idea of these instruments as toys because he believed that toys and games served as some of the first 'experiments of illustration.' Maxwell thought it likely that the earliest characteristics of mechanical motion had made themselves 'visible' to observers in play. Lacking the complexity of ordinary life, games were able to illustrate phenomena such as the reciprocity of force. I argue that when read in this context, Maxwell's dynamical top seems all the more important, as it draws attention to the fact that after millennia of playing with tops and learning about rotation from their motion, there were still aspects of their rotation which had not been observed. Maxwell's use of scientific toys to make physical phenomena visible should therefore be understood not merely as a reflection of his playful spirit, but also as a valuable part of his scientific practice.

II. "to see him at play"

It was no secret that practitioners of science in the nineteenth century loved toys: particularly toys which took advantage of well-understood dynamical or optical principles. They played with them for individual pleasure and, as I demonstrated in the last chapter, used them to instruct others. Moreover, scientific practitioners were often involved in the construction of new toys. In 1870, a London correspondent for the Welsh Western Mail used the ingenuity of three toys--David Brewster's kaleidoscope and stereoscope and Charles Wheatstone's "Chameleon Top"—to assert that while earlier in the century John Ayrton Paris had turned Philosophy in Sport into Science in Earnest, modern practitioners did the opposite: “science in earnest making philosophy in sport.”[13]

In scholarship on nineteenth-century science, Maxwell is probably the scientific practitioners whose fondness for toys has been most frequently discussed.[14] In one of those strange coincidences which the study of play so often makes apparent, Maxwell was likely born with images of play in view: what appear to be sketches of boys playing with tops and hoops and dressed up as soldiers appear on the fireplace tiling of his home at 14 India Street, Edinburgh (Figure 3-2). One is almost tempted to suggest that such play shaped the course of Maxwell’s life; indeed, one likely would have had Maxwell’s support in drawing such a conclusion for, as I will discuss, he was a supporter of knowledge produced by such playful connections.

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[13] “London,” *Western Mail*, January 29, 1870.
[14] See Daniel Brown, *Poetry of Victorian Scientists: Style, Science, and Nonsense* (Cambridge: Cambridge University Press, 2015).


Figure 3-2: Photo (taken by author) of the tiling found within the room where Maxwell was born at 14 India Street, Edinburgh (now referred to as "Exhibition Room II" by the James Clerk Maxwell Foundation).

While Maxwell was not a sportsman and seldom took part in the games of his schoolfellows, his biography is full of accounts of Maxwell at play: running around outdoors; blowing soap bubbles; designing his own phenakistiscopic animations; playing with his dog Toby; horse-riding; playing with children (Figure 3-3); playing with pearies and "bools" (marbles); inventing cyphers; attending meetings of the Royal Society of Edinburgh as an "amusement"; swimming; dancing; playing "Hunt the Gowk" (April Fool's Day) pranks; doing archery; playing with his diabolo; skating; making puns; sculling; and playing whist and chess.[15] Maxwell's playfulness was also demonstrated by his nonsensical and satirical poetry and in the riddles and puns which frequently appear in his correspondence with fellow practitioners of science such as Peter Guthrie Tait.

[15] Campbell and Garnett, *Life of James Clerk Maxwell*, 10, 33, 36-39, 51, 53-57, 63, 65, 82, 152, and 66.

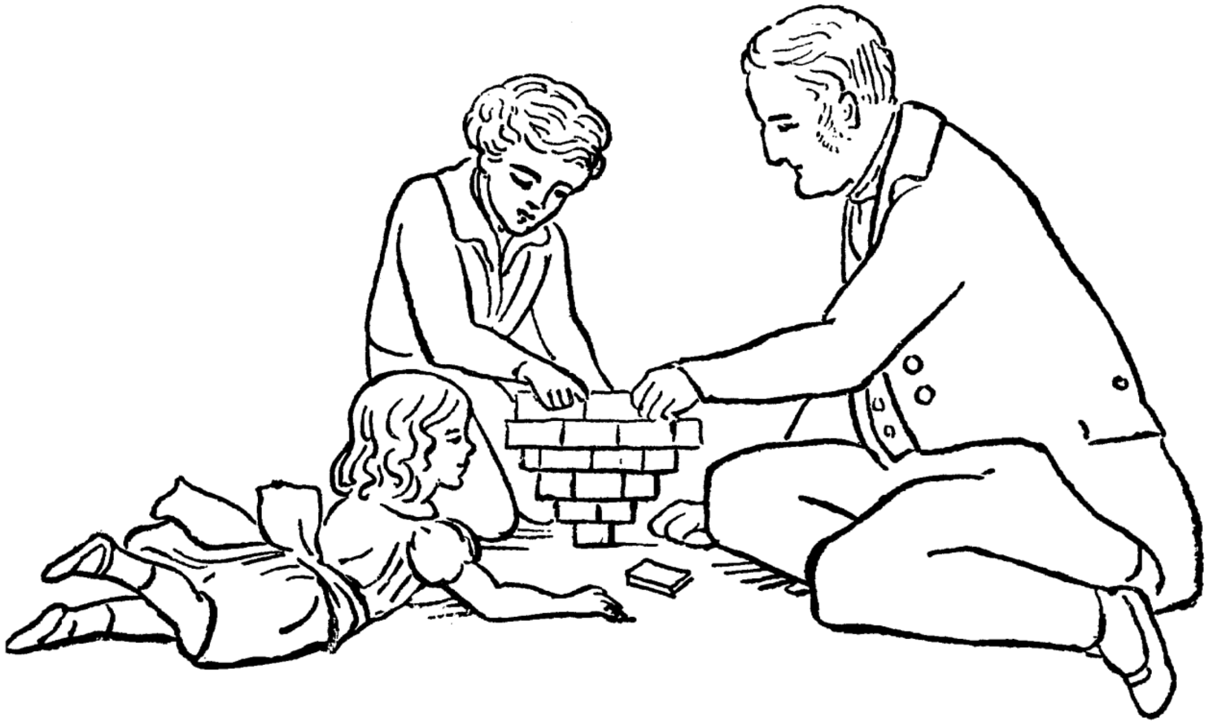

Figure 3-3: Illustration of Maxwell (middle, age 12) and his father (right) helping Lord Charles Scott (left, age 4) to play in 1843.[16]

Maxwell's play—especially his childhood recreations—has been explicitly tied to his later scientific work by literary scholars, biographers, and historians. Campbell and Garnett suggest that:

> despite the popular adage, 'Work when you work,' etc., [Maxwell's] play was always passing into work and work into play. In twirling his magic discs [phenakistiscope], his mind was already busy with the cause of optical phenomena. He plied the devil on-two-sticks [diabolo] with the same eager industry, and with the same simple enjoyment, with which he afterwards spun his dynamical top. And amidst his profoundest investigations, whether about the Rings of Saturn or the Lines of Force, or the molecular structure of material things, the playful spirit of his boyhood was ever ready to break forth.[17]

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[16] Campbell and Garnett, *Life of James Clerk Maxwell*, 40.
[17] Campbell and Garnett, *Life of James Clerk Maxwell*, 429.

More recently, an article from physicist Malcolm Longair has claimed that Maxwell's optical work was inspired by optical toys of the 1830s,[18] while Daniel Brown's *The Poetry of Victorian Scientists* (2012) has made a persuasive case that the nonsensical and satirical poems Maxwell wrote while at Cambridge served to interrogate the epistemological grounds of his scientific practice and served as a space for expressing disagreement.[19]

While scholarship on Maxwell has treated his play with toys as a forerunner to his scientific work, nineteenth-century 'toys' and 'playthings' were generally treated as separate from, or even diametric to, scientific instruments, even though they were often made by the same instrument makers. It is this opposition, for instance, that allowed instrument maker John or Edward Troughton to warn that instruments of less than one foot in diameter may be considered, "for astronomy, as little better than playthings."[20] This separation is unsurprising, given that 'toy' was principally defined in Johnson's dictionary as "a petty commodity; a trifle; a thing of no value."[21] Psychologist Nicholas Wade has pointed out that some objects were treated as "philosophical toys": instruments that "provided popular amusement as well as experimental assistance."[22] Jordi Cat explains that objects like spinning tops, magic lanterns, stereoscopes, and photographic cameras in the nineteenth century, which were both popular and commercially successful, would have been more readily available for scientific use.[23] But I argue that even philosophical toys were typically separated from scientific instruments temporally: that is,

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[18] Malcolm S. Longair, "Maxwell and the Science of Colour," *Philosophical Transactions of the Royal Society* 366 (Jan. 2008): 1688.
[19] Brown, *Poetry of Victorian Scientists*, 6, 37.
[20] Charles Babbage, *Reflections on the Decline of Science in England, and Some of Its Causes* (London: B. Fellowes, 1830), 98.
[21] Samuel Johnson, *A Dictionary of the English Language* (Dublin: W. G. Jones, 1768).
[22] Nicholas J. Wade, "Philosophical Instruments and Toys: Optical Devices Extending the Art of Seeing," *Journal of the History of the Neurosciences* 13, no. 1 (2004).
[23] Cat, *Maxwell, Sutton, and the Birth of Color Photography*, 36.

scientific instruments generally *become* toys once the phenomena they exhibit is well understood.

Despite working at a time when scientific practitioners were describing themselves as "scientific workers," playfulness of any kind was, for Maxwell, a companion to the discovery of scientific facts. To be sure, fun *alone* was not enough to determine truth. This seems to be what Maxwell is warning against in an inaugural lecture at King's College in 1860, in which he asserts that natural philosophy means "leav[ing] on one side […] the feelings which incline us to take pleasure in what we see, without inquiring into what lies behind it."[24] Yet as long as one used pleasure as a motive for further investigation, play could be coupled to scientific practice. Consider, for instance, Maxwell's description of his scientific studies in an 1850 letter to Lewis Campbell. Maxell begins the letter by stating that "At Practical Mechanics I have been turning Devils of sorts," alluding both to his passion for mechanical science and implying that his play with his diabolo was itself a form of scientific study.[25] Moreover, Maxwell argued that scientific practice should itself produce a unique "kind of enjoyment" and encouraged his students to cherish "any sensation of pleasure […] in the opening up of the mind to the perception of truth."[26]

On occasion, Maxwell's writings even approached a stronger defense of playfulness in science, reminiscent of Paul Feyerabend's argument in *Against Method* (1973), in which science is not merely amenable to play; rather, starting from a place of play might lead to unexpected combinations of ideas and through them to solutions to unrealized problems.[27] For instance, in

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[24] Maxwell, "Inaugural Lecture at King's College, London. October 1860," 662.
[25] Maxwell, *Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:189.
[26] Maxwell, "Inaugural Lecture at King's College, London. October 1860," 674; James Clerk Maxwell, "Lectures on Faraday's Lines of Force," in *The Scientific Letters and Papers of James Clerk Maxwell: 1862-1873*, ed. P. M. Harman (Cambridge: Cambridge University Press), 2:793.
[27] Paul Feyerabend, *Against Method* (London: Verso, 2010), 157.

his 1873 poem "Molecular Evolution," Maxwell suggests that embracing playful science can reveal scientific truths undiscoverable by other means. In this poem, Maxwell describes the relationship between the British Association for the Advancement of Science (BAAS) and the Metropolitan Red Lions Club, a club which met to drink, smoke, ridicule the BAAS proceedings, and partake in "scientific jests."[28] When they leave the more professional setting of the BAAS for their social club, the "British asses" are "transformed to wild Red Lions" who "ramp and rave":

> Thus, by a swift metamorphosis,
> Wisdom turns wit, and science joke,
> Nonsense is incense to our noses,
> For when Red Lions speak, they smoke.[29]

One might predict that the incense and raving would distort the senses in a way antithetical to the production of scientific knowledge, but Maxwell emphasizes that such playful nonsense is in fact a path to scientific truth unachievable by other means:

> Hail, Nonsense! dry nurse of Red Lions,
> From thee the wise their wisdom learn,
> From thee they cull those truths of science,
> Which into thee again they turn.
>
> What combinations of ideas,
> Nonsense alone can wisely form!
> What sage has half the power that she has,
> To take the towers of Truth by storm?

What Maxwell suggests here is a cyclical process in which the Red Lions' scientific jests and buffoonery destabilize what Maxwell later calls the "rules of rigid reason" and allow ideas to fit together in new ways which reveal new scientific truths; these ideas are then brought back into

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[28] "The Scientists and the Lions," c1926, MS ADD 44, Red Lions Notebook, University College London Collection, National Archives Kew, London, U.K.
[29] James Clerk Maxwell, "Molecular Evolution," *Nature* 8 (2 Oct. 1873): 473.

professional scientific discourse, at which point the process repeats. In short, as Daniel Brown recognizes, the poem suggests that the "elusive and teasing hybrid meanings and associations that arise in the mind at play, as it makes and contemplates puns and other forms of wit" can provide real advancements for science.[30]

This is not to say that Maxwell believed that the scientific process was always amenable to play. The activities of the Red Lions could also be positioned against scientific practice. For instance, in another poem, "Song of the Cub," a practitioner inspired by John Tyndall's famous Belfast Address to the BAAS attends the Red Lions meeting expecting to find "high feasts of Science" but instead finds that "science seems turned into fun."[31] Deafened by the "roar of Red Lions," the speaker turns away from their solemn devotion to science in favor of the fun of the club, seeming to give up (at least for a time) on the mysteries that had prompted their investigation of nature.

Like his contemporaries, Maxwell often emphasized that producing scientific knowledge could be a struggle, requiring the devotion of energy, time, and much labor.[32] And while "Molecular Evolution" suggested that nonsense could lead to unique truths, his article on "Molecules," published only a week earlier in *Nature*, suggests the same about "scientific work," which leaves "the worker […] in possession of methods which nothing but scientific work could have led him to invent, and […] places him in a position from which many regions of nature, besides that which he has been studying, appear under a new aspect."[33] For Maxwell, scientific

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[30] Brown, *Poetry of Victorian Scientists*, 178.
[31] James Clerk Maxwell, "Song of the Cub. Belfast, 1874," in *The Life of James Clerk Maxwell*, ed. Lewis Campbell and William Garnett (London: Macmillan, 1882), 638.
[32] See, for instance, Maxwell, "Inaugural Lecture at King's College, London. October 1860," 673; James Clerk Maxwell, "Introductory Lecture on Experimental Physics," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press, 1890), 2:247-8.
[33] James Clerk Maxwell, "Molecules," *Nature* 8 (1873): 440.

practice functioned best when one was not overly solemn about the approach to science, but also remained willing to do scientific work.

Maxwell was rarely explicit about the manner in which his own play benefitted his scientific work. It is often unclear how seriously one is meant to take his suggestion that his play was part of his scientific study. In an 1850 letter to Lewis Campbell, for instance, Maxwell describes how, as part of his Cambridge studies, he plans to undertake "Simple mechanical problems to produce that knack of solving problems […] for experimental philosophy, twisting and bending certain glass and metal rods, making jellies, unannealed glass, and crystals, and dissecting eyes – and playing Devils [playing with his diabolo, Figure 3-4]."[34] While hinting at a connection between his play with devil sticks and his mechanical knowledge, the primary intent here seems to be humor. The supposed attempt to bring the devil sticks into the scientific domain is challenged by their separation from those activities by the dash. Similarly, in an earlier (26 April 1848) letter to Campbell, Maxwell describes his typical day thusly:

> I have been reading Xenophon's *Memorabilia* after breakfast; also a French collection book. This from 9 to 11. Then a game of the Devil, of whom there is a duality and a quaternity of sticks, so that I can play either conjunctly or severally. I can jump over him and bring him round without leaving go the sticks. I can also keep him up behind me.
>
> Then I go in again to science...[35]

The reference to a "quaternity of sticks"—likely a reference to William Hamilton's work on quaternions, a number system that allowed for complex numbers and could be applied to three-dimensional space—again suggests that even while he is playing with the sticks, he is thinking of science. Yet here too the scientific work is again distanced from his play, this time by a break in

[34] Maxwell, *Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:191.
[35] Maxwell, *Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:70.

paragraphs.[36] However, while Maxwell never explicitly tied his devil sticks to his scientific work, another rotatory toy, the top, did play a prominent role in his scientific practice in the 1850s.

Figure 3-4: Photo (taken by author) of a replica of James Clerk Maxwell's 'devil sticks' or diabolo at the James Clerk Maxwell Foundation.

III. Pearies as Playthings

Before investigating the workings of and rhetoric surrounding Maxwell's color and dynamical tops, it is important to understand the context for tops as *toys* in Victorian Britain. D. W. Gould has catalogued the variety of forms nineteenth-century tops took: twirlers, peg tops, teetotums, whipping tops, gyroscopes, magnetic tops, helixes, and more.[37] Wood, bone, and ivory tops were popular in the nineteenth century.[38] In addition to taking several forms, the top was also invoked metaphorically in a variety of contexts. For instance, William Wordsworth tied the top to the French Revolution, comparing the frenzied crowds gathered round the guillotines to children playing with whirligigs, as a way of emphasizing the cruelty of this entertainment and the

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[36] Maxwell's previous letter to Campbell (November 1847) mentions an interest in Hamilton's essays on logic (Maxwell, *Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:69). This, along with the fact that a talk from Hamilton on the subject of quaternions was published in 1847 *Proceedings of Irish Royal Academy* suggests that Maxwell would have been aware of quaternions by this time (William Hamilton, "November 11, 1844," *Proceedings of the Royal Irish Academy* 3, no. 48 (1847)).
[37] D. W. Gould, *The Top* (Folkestone, England: Bailey Brothers and Swinfen Limited, 1973), 36-37.
[38] Gerard L'E. Turner, *Nineteenth-Century Scientific Instruments* (Berkely, University of California Press, 1983), 295.

frivolity with which human life was being treated.[39] Later in the century, writers like Margaret Oliphant and H. G. Wells used the symbol of the top to illustrate the changeableness of human opinion.[40]

Tops' association with frivolity comes from their association with childhood, or, more particularly in the nineteenth century, with boyhood. For instance, in Mary Ann Kilner's it-narrative *Memoirs of a Peg-Top* (c. 1800), peg tops are chosen as an amusement which "young Gentlemen" were particularly interested in.[41] While the text allows that young girls may be interested in tops, Kilner suggests that they can never really be familiar with tops because they lack the skill necessary to properly spin them.[42] Later in the century, girls playing with tops became more common, although their tops still often differed in shape and use from the peg tops boys commonly played with.[43] Folklorist Steve Roud has observed that women's memories of tops in the late nineteenth- and early twentieth-centuries "focus on what might be called the 'gentle art' of top-spinning: they record coloring the tops with chalk or pieces of paper to make pretty patterns, and the pleasures of watching tops spinning. Men, on the other hand, remember the competitive games, and the danger to life and limb involved."[44] Among scientific practitioners, at least, tops continued to be treated as boys' playthings throughout the century: in

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[39] William Wordsworth, *The Prelude, or, Growth of a Poet's Mind; an Autobiographical Poem* (London: E. Moxon, 1850), X.363-74.
[40] Margaret Oliphant and F. R. Oliphant, *The Victorian Age of English Literature* (London: Percival and Co., 1892), 2:44; H. G. Wells, "The Rediscovery of the Unique," *Fortnightly Review* 50 (1891): 109.
[41] Mary Ann Kilner, *Memoirs of a Peg-Top* (York: T. Wilson and R. Spence, c1800), vi.
[42] Kilner, *Memoirs of a Peg-Top,* 69.
[43] This was not, of course, a strictly enforced rule. The section on "Tops" in *Kate Greenaway's Book of Games* (1889), for instance, includes an illustration of a girl and two boys playing with similar peg tops (Kate Greenaway, *Kate Greenaway's Book of Games* (London: George Routledge & Sons, 1889), 13-4).
[44] Steve Roud, *The Lore of the Playground: One Hundred Years of Children's Games, Rhymes, and Traditions* (London: Random House, 2011), 151.

a lecture to the British Association on "Spinning Tops" in 1890, the Irish engineer John Perry (1850 – 1920) references boys playing with tops several times, but omits girls entirely.[45]

This association is preserved in Maxwell's poem celebrating "pearies" or peg tops: a poem given the rather lengthy title "TORTO VOLITANS SUB VERBERE TURBO QUEM PUERI MAGNO IN GYRO VACUA ATRIA CIRCUM INTENTI LUDO EXERCENT" (1844) in reference to Virgil's *Aeneid*.[46] The poem describes a group of boys battling with peg tops as a great military engagement, in which the clashing peg tops (also gendered masculine) attempt to run each other through with their "destructive steel" (the iron pegs).[47] An illustration of the type of game Maxwell is describing can be observed in Kilner's *Memoirs of a Peg-Top* (Figure 3-5).[48] Homeric simile heightens the stakes of the martial scene: armies of peg tops swoop like falcons and descend like "Maia's son" to crash against their enemies. The hyperbole puts readers in a position to understand that the stakes are simultaneously quite low and very high: when Maxwell describes "the wail / Of ruined boys, their pearie split, and all, All lost,"[49] the reader is made aware of both the triviality of these toys and their real value to the boys who play with them. The explicit "morals" which Maxwell's poem suggests the reader "may […] from the pearie draw" is that such loss is part of "this ever-changing world." But another lesson implicit in the poem is

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[45] John Perry, *Spinning Tops: The "Operatives' Lecture" of the British Association Meeting at Leeds, 6th September, 1890* (London: Society for Promoting Christian Knowledge, 1890).

[46] As translated by English translator John Dryden, "TORTO VOLITANS SUB VERBERE TURBO QUEM PUERI MAGNO IN GYRO VACUA ATRIA CIRCUM INTENTI LUDO EXERCENT" means "As young striplings whip the top for sport, On the smooth pavement of an empty court" (Alexander Chalmers, *The Works of the English Poets, From Chaucer to Cowper* (London: J. Johnson, 1810), 19:410). Wordsworth's reference to the top was also inspired by Virgil's *Aeneid*, where the comparison of Amata's ravings to boys playing with a top in an empty court turns the tops into markers of the frivolity of all human affairs, from the perspective of the gods (Arnd Bohm, "Toys of Wrath: 'The Prelude' 10: 363-74 and 'Aeneid' 7: 374-84," *Wordsworth Circle* 36, no. 3 (2005), 125).

[47] James Clerk Maxwell, "Torto Volitans Sub Verbere Turbo Quem Pueri Magno in Gyro Vacua Atria Circum Intenti Ludo Exercent" in *The Life of James Clerk Maxwell*, ed. Lewis Campbell and William Garnett (London: Macmillan 1882).

[48] Kilner, *Memoirs of a Peg-Top*, 17.

[49] Maxwell, "Torto Volitans Sub Verbere Turbo Quem Pueri Magno in Gyro Vacua Atria Circum Intenti Ludo Exercent."

that, despite being "wooden playthings," one can draw large, universal lessons from these seemingly trivial things.

Figure 3-5: Illustration of boys battling with peg-tops in Kilner, *Memoirs of a Peg-Top* (York: T. Wilson and R. Spence, c. 1800).

The ability to draw analogies between the seemingly trivial top and the larger universe is also suggested by the poem's beginning, which submits that "the secret of the Top" was inspired by "the endless music of the spheres": "the planets round the central sun." It is possible that Maxwell arrived at this comparison through scientific literature, as comparisons between spinning tops and spinning planets were common in nineteenth-century science writing.[50] Maxwell was only thirteen when he wrote this poem, but he had already attended meetings of the Royal Society of Edinburgh (RSE) and was a mere two years away from having his first paper presented to that body. He likely knew that yet another connotation of tops at the time was a connection between their mysterious, almost miraculous motion and the motion of the heavens. As Maxwell would later acknowledge, before presenting his dynamical top to the RSE in 1857, "To those who study the progress of exact science, the common spinning-top is a symbol of the

[50] For instance, astronomer John Herschel used spinning peg-tops and teetotums as models for the precession of the earth's equinoxes in his scientific writing (John Herschel, *Outline of Astronomy* (Philadelphia: Lea & Blanchard, 1849), 189).

labours and the perplexities of men who had successfully threaded the mazes of planetary motions."[51]

The varied connotations and symbolic resonances of the top can be explained in part by the indefiniteness of what classifies an object as a 'top.' Today, the *Oxford English Dictionary* definition of "top" as "a toy of various shapes (cylindrical, obconic, etc.), but always of circular section, with a point on which it is made to spin"[52] is contradicted by its definition of "dreidel" which does not have a circular section but is defined as "a four-sided spinning top."[53] In the nineteenth century, the definition in Johnson's *Dictionary* (written for the 1768 edition and still present in the 1876 edition) of a "top" as an "inverted conoid which children set to turn on the point, continuing its motion with a whip"[54] was contradicted by adult's play with tops, the increasing popularity of non-whipped tops, and by the development of spherical tops.[55] For scientific definitions of the "top," one can do no better than to turn to German mathematician Felix Klein, whose thorough treatise on *The Theory of the Top* (1895) defines a top as "a rigid body subject to gravity, whose mass is symmetrically distributed around an axis of the body, and which, by means of an appropriate device, is fixed in space at one point of the symmetry of axis."[56] But Klein also readily admitted that scientific investigations of the motions of 'tops' rarely describe the actual action of everyday children's tops, which are not truly fixed at one point.[57] In truth, any rotating body can be classified as a 'top.' In choosing this label, however,

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[51] Maxwell, "On a Dynamical Top," 1:248.
[52] "Top, N.2," *Oxford English Dictionary*, http://www.oed.com/view/Entry/203332?rskey=tPCgBk&result=2&isAdvanced=false.
[53] "Dreidel, N.," *Oxford English Dictionary*, http://www.oed.com/view/Entry/242604?redirectedFrom=dreidel.
[54] Johnson, *A Dictionary of the English Language* (1768); Samuel Johnson, *A Dictionary of the English Language*, ed. Robert Gordon Latham (London: Longmans, Green, 1876).
[55] See, for instance, Perry, *Spinning Tops*, 74. Spherical tops of the type described by Perry, in which the center of gravity does not coincide with the geometric center, were eventually developed into the very popular 'Tippe Top' or 'Flip Top.'
[56] Felix Klein and Arnold Sommerfield, *The Theory of the Top* (New York: Springer, 2010), 1:1.
[57] Klein and Sommerfield, *The Theory of the Top*, 1:2.

one opens the door to the associations of Victorian boyhood and play. In the next section, I investigate how Maxwell's scientific practice benefitted from allowing these associations in the case of his color tops.

IV. "a few thoughts on top-spinning and sensation generally"

What Maxwell humbly described in 1855, in a letter to Cecil James Munro, as "a few thoughts on top-spinning and sensation generally"[58] eventually resulted in Maxwell's 'color top' (Figure 3-6) becoming one of the most famous instruments of his scientific practice. The importance of this top to Maxwell's historical reputation is evidenced by the fact that in Alexander Stoddart's statue of Maxwell at St Andrew Square in Edinburgh (unveiled in 2008), the color top is prominently displayed in Maxwell's hand (Figure 3-7). But why study color using a "top"?

Figure 3-6: Photograph of Maxwell's color top from 1855, taken by Walter Andrews in 1962 and colorized by Kelvin Fagan in 2015.[59]

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[58] James Clerk Maxwell, "Letter to Cecil James Monro. 19 February 1855," in *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, ed. P. M. Harman (Cambridge: Cambridge University Press 1990), 1:282.
[59] Kelvin Fagan, "Maxwell's Colour Wheel (Colour Image)," 2015, P2000, University of Cambridge Digital Library, https://cudl.lib.cam.ac.uk/view/PH-CAVENDISH-P-02000/1. Creative Commons License (CC BY-NC 3.0), https://creativecommons.org/licenses/by-nc/3.0/.

Figure 3-7: Photo (taken by Jacqueline Banerjee) of Alexander Stoddart's 2008 statue of an older Maxwell (and his dog Toby), with the color top in Maxwell's left hand.[60]

Maxwell was not the first to mimic additive color mixing by taking advantage of persistence of vision through rotation. As I have already mentioned, children's tops were often colored to create surprising or aesthetically pleasing patterns through the combinations of various colors. Maxwell himself designed tops like this as a child. [61] Maxwell was introduced to the idea of formally studying additive color mixing in the summer of 1849, through the experiments of his mentor, fellow physicist James Forbes, which mixed colors by spinning colored discs.[62] At the time, Forbes was using tinted papers supplied by decorative artist D. R. Hay to place color mixtures into a triangular classification of colors defined by the three primary colors of red, blue, and yellow.[63] Maxwell's work was also influenced by British polymath Thomas Young, whose suggested that red, green, and violet should be considered the three primary constituents of white

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[60] Jaqueline Banerjee and Alexander Stoddart, "Monument to James Clerk Maxwell, FRS, FRSE (1831-1879)," *Victorian Web*, 23 Mar. 2015, https://victorianweb.org/science/maxwell/3.html.
[61] TrinityCollegeLibrary1695, "Mrs Wedderburn's Abigail," *Trinity College Library, Cambridge Treasures from the Collection*, 9 March 2017, https://trinitycollegelibrarycambridge.wordpress.com/2017/03/09/mrs-wedderburns-abigail/.
[62] James Clerk Maxwell, "Letter to James David Forbes. 12 May 1855," in *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, ed. P. M. Harman (Cambridge: Cambridge University Press 1990), 1:301
[63] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:16.

light and put forth the three-receptor theory of color vision.[64] Young suggested that light receptors in the retina of the eye acted as resonators, excited by incoming light waves. However, as it was unlikely that each point on the retina had infinite receptors for each color, Young thought that each sensor probably consisted of three portions, constructing the color spectrum from three principal colors.[65] This was, however, a qualitative rather than a quantitative theory: the necessary proportions for the observation of each color were undetermined.

Maxwell was able to contribute to quantitative color theory through his own modifications to Forbes's spinning discs.[66] Forbes's method was to spin overlapping colored discs; the proportions of each color were secured by screwing the discs down onto a disc of India rubber.[67] In addition to creating colored discs which could be brought together in different proportions, Maxwell added a second set of sectors in the center of the disc so that color comparisons could be made, as seen in Figure 3-6.[68] Black sectors could also be added to eliminate the effect of brightness. Later, Maxwell had a smaller version, which could be spun more quickly, constructed for him by the optical instrument maker Bryson of Edinburgh (Figure 3-8). This version of the top had a percentage scale around its edge so that the exact proportion of color necessary to match the central color sample could be quantified.[69] With this instrument Maxwell was able to demonstrate that all colors could be constructed from different proportions of three primary colors and to draw attention to the fact that mixing lights produces different colors than mixing pigments.[70] Although Maxwell found that the necessary proportions differed

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[64] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:17.
[65] Longair, "Maxwell and the Science of Colour," 1688.
[66] See his letter to George Wilson for a detailed description of the "top or teetotum" (Maxwell, "Letter to George Wilson. 4 January 1855," in *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862,* ed. P. M. Harman, 1:271-272).
[67] Maxwell, "Letter to James David Forbes. 12 May 1855," 1:302, f.8.
[68] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:17.
[69] "Disks from James Clerk Maxwell's Colour Top," National Museums Scotland, https://www.nms.ac.uk/explore-our-collections/stories/science-and-technology/james-clerk-maxwell-inventions/james-clerk-maxwell/colour-disks/.
[70] Longair, "Maxwell and the Science of Colour," 1688.

slightly between observers (leading to his use of the color top to investigate color blindness),[71] he was able to experimentally determine color equations expressing color in a formula such as C = *a*X + *b*Y + *c*Z, where X, Y, and Z are arbitrarily chosen standard colors, and *a*, *b*, and *c* are numerical coefficients.[72] This quantification allowed him to map colors onto a color triangle, defined by three primary colors, on which the distance from the corners indicated how much of each primary color was necessary (Figure 3-9).[73]

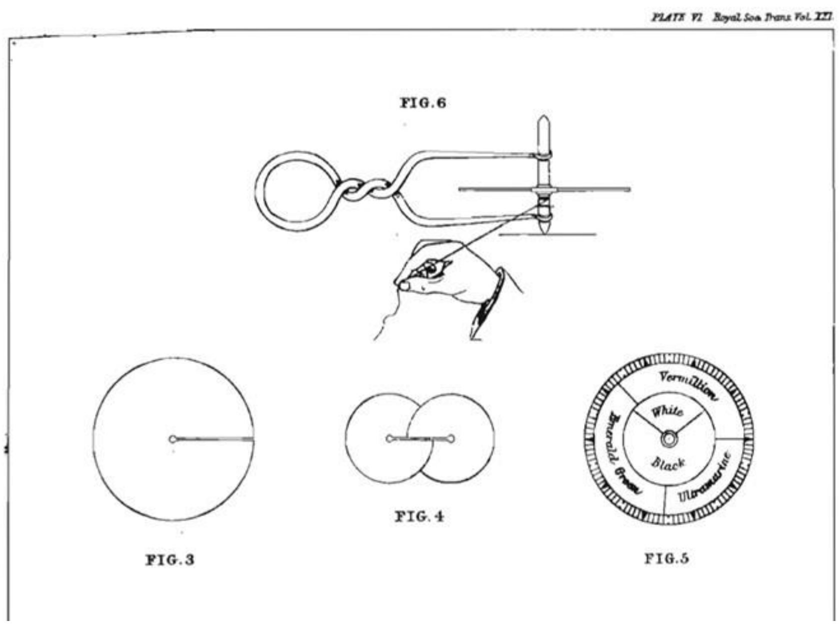

Figure 3-8: Published diagram of the color top, as it was constructed by Bryson of Edinburgh.[74]

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[71] James Clerk Maxwell, "Manuscript on the Comparison of Colours Using a Spinning Top. 27 February 1855," in *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, ed. P. M. Harman (Cambridge: Cambridge University Press 1990), 1:286.

[72] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:17; Peter Guthrie Tait, "James Clerk Maxwell," *Proceedings of the Royal Society of Edinburgh* 10, no. 105 (1879-80): 336.

For example, Maxwell experimentally determined that:

$$\left.\begin{matrix} .37\,Vermilion \\ +\,.27\,Ultramarine \\ +\,.36\,Emerald\ Green \end{matrix}\right\} = \begin{cases} .28\,White \\ +\,.72\,Black \end{cases}$$

(James Clerk Maxwell, "Experiments on Colour as Perceived by the Eye, with Remarks on Colour-Blindness," *Proceedings of the Royal Society of Edinburgh* 3 (19 Mar. 1855): 300).

[73] Longair, "Maxwell and the Science of Colour," 1692.

[74] James Clerk Maxwell, "Experiments on Colour, as Perceived by the Eye, with Remarks on Colour-Blindness. Communicated by Dr. Gregory," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press 1890), 1:Plate I.

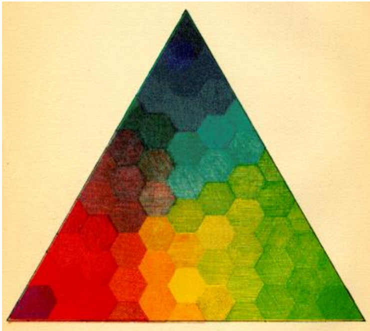

Figure 3-9: Illustration of Maxwell's original color triangle.[75]

In addition to the new sectors Maxwell added to the discs, he was also the first to rotate these discs in the form of a "common top," invoking the labels playful connotations.[76] Other physicists had used other devices for color mixing, but not "tops." Maxwell (and others) describe Newton's apparatus for attempting to recreate white through the combination of colors as a "disc."[77] Belgian physicist Joseph Plateau had combined Prussian blue and gamboge in 1819, also using a "disc."[78] The closest Forbes comes in his published work is his reference to a rotating "wheel" in his "Hints towards a Classification of Colours" (1849).[79] Hermann von Helmholtz's method was to illuminate a screen of white paper with different colors of light.[80] All references I have found to the "color top" or "colour top" before 1860 are associated with Maxwell, and Cassell's *Encyclopaedic Dictionary* (1888) also defines the "Colour-top" as "a form of top modified by the late J. Clerk-Maxwell for colour experiments."[81] Maxwell's priority in this regard seems certain.

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[75] Campbell and Garnett, *Life of James Clerk Maxwell*, Plate I.
[76] Maxwell, "Experiments on Colour," in *The Scientific Papers of James Clerk Maxwell*, 1:126.
[77] Maxwell, "Experiments on Colour," in *The Scientific Papers of James Clerk Maxwell*, 1:145.
[78] James Clerk Maxwell, "On the Theory of Compound Colours with reference to Mixtures of Blue and Yellow Light," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press, 1890), 1:243.
[79] James D. Forbes, "Hints Towards a Classification of Colours," *Philosophical Magazine* 34 (1849): 166.
[80] Maxwell, "Experiments on Colour," in *The Scientific Papers of James Clerk Maxwell*, 1:152.
[81] *The Encyclopaedic Dictionary* (London: Cassell), 7.

Maxwell insisted in a letter to George Wilson in 1855 that "the principal use of the top is to obtain colour-equations,"[82] yet Maxwell's written descriptions of the top often reminded readers of its recreational uses. In his correspondence, Maxwell described the mixing of colors as a form of "recreation" and would occasionally discuss his experiments with the color top by referring to them, somewhat disingenuously, simply as "top spinning."[83] In a letter to his father in 1855, rather than describing his first presentation of the color top before the RSE as scientific work, he calls it his "colour trick," as though even in this professional setting the value of the top was not the creation of new scientific knowledge, but rather the exhibition of his toy.[84] Alexander Macmillan recalled that it was also one of Maxwell's many toys for entertaining children.[85]

Maxwell's decision to label the instrument a "top"—despite the fact that its fixed axis of rotation means that it actually is not the type of "common top" children play with—framed the instrument as a pleasurable thing to look at and benefitted Maxwell's scientific project. Observations of the color top would have been tedious, and likely eye-straining. Maxwell had to slowly adjust the proportions of colors for the observer to attempt to match, and there were upwards of 100 different artificial colors to be observed.[86] Furthermore, Maxwell's experiments had the additional requirement that no combination be repeated in a day, in order to reduce subjective bias. Light also had to be standardized as much as possible, meaning that observations should be tested at the same time in the same weather facing the same direction. Therefore, such

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[82] Maxwell, "Letter to George Wilson. 4 January 1855," 1: 272.
[83] Maxwell, "Letter to Cecil James Monro. 19 February 1855," 1:282; James Clerk Maxwell, "Letter to Cecil James Monro. 24 January 1860," in *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862,* ed. P. M. Harman (Cambridge: Cambridge University Press 1990), 1:644.
[84] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:65.
[85] Campbell and Garnett, *Life of James Clerk Maxwell*, 41.
[86] James Clerk Maxwell, "Account of Experiments on the Perception of Colour," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press, 1890), 1:263.

experiments would have been a significant time commitment. Describing his own experience, Maxwell admits in his "Account of Experiments on the Perception of Colour" (1857) that "I think that the human eye has seldom been subjected to so severe a test of its power of distinguishing colours."[87] In 1859, when a color blind student (possibly his pupil James Simpson)[88] who Maxwell had been experimenting on was absent from his class, Maxwell joked in a letter to Tait that he hoped it was not "in fear of the top."[89] There was perhaps a kernel of truth in this.

To verify his findings, Maxwell needed to convince as many people as possible to act as observers. When he shared an "Account of Experiments on the Perception of Colour" with the *Philosophical Magazine* in 1857, he emphasized that his was "to induce those who have good eyes to subject them to the same trial of skill in distinguishing tints."[90] Multiple observers were necessary both because Maxwell wanted to test whether all human eyes perceived color the same way and because he believed that there was a degree of skill involved in distinguishing between colors. Although he found that "inaccurate observers" might be trained to perceive these differences, his practical solution seems to have been to seek out other eyes which were more accurate.[91] Maxwell had Bryson prepare multiple versions of the top "to afford different observers the means of testing and comparing results independently obtained,"[92] and emphasized the simplicity of the apparatus to encourage others to build their own: "it may be easily extemporized. Any rotary apparatus which will keep a disc revolving steadily and rapidly in a good light without noise or disturbance, and can be easily stopped and shifted, will do as well as

[87] Maxwell, "Experiments on the Perception of Colour," 1:268.
[88] Maxwell, "Theory of Compound Colours," 1:652.
[89] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:605.
[90] Maxwell, "Experiments on the Perception of Colour," 1:264.
[91] Maxwell, "Experiments on the Perception of Colour," 1:268.
[92] Maxwell, "Experiments on Colour," in *The Scientific Papers of James Clerk Maxwell*, 1:127.

the contrivance of the spinning-top."[93] As Jordi Cat observes, in this way Maxwell was able to enlarge the scope of influence of his work and prompt others to replicate his instruments, which gave him the best chance of having others reproduce his results.[94] For instance, after spinning the top in May of 1855, William Thomson ordered the appropriate colored papers from Hay the following year in order to replicate the results.[95] I have demonstrated replicas of Maxwell's color top that I made in presentations for the University of Michigan's Institute for Humanities and the North American Victorian Studies Association, and I can offer at least anecdotal evidence that those I handed the top to seemed to be quite interested in playing with it.

The "top" appellation may also have helped to draw more eyes within the masculine atmosphere of the Royal Society of Edinburgh. Other scientific practitioners, such as William Thomson and Peter Guthrie Tait, also documented playing with tops with their colleagues.[96] It seems likely that these practitioners would have viewed this pleasurable activity as a continuation of their boyhood pursuits. The idea of "men of science" gathered round Maxwell's top does recall Maxwell's poetic image of boys playing with tops and may have encouraged observation of the top through nostalgia. Maxwell never specifically states that the color top was a toy/instrument for boys or men (although he does always refer to the observers of the top using masculine pronouns).[97] Yet later commercial adaptations of the color top, such as John Graham's "Kaleidoscopic Colour-Top" did appear in texts aimed at boys, such as John Henry Pepper's *Boy's Playbook of Science* (1860), suggesting that perhaps the association was preserved.[98]

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[93] Maxwell, "Experiments on the Perception of Colour," 1:264.
[94] Cat, *Maxwell, Sutton, and the Birth of Color Photography*, 84.
[95] Cat, *Maxwell, Sutton, and the Birth of Color Photography*, 85.
[96] Silvanus P. Thompson, *The Life of William Thomson, Baron Kelvin of Largs* (London: Macmillan) 2:587.
[97] See Maxwell, "Experiments on Colour," in *The Scientific Papers of James Clerk Maxwell*, 1:129.
[98] John Henry Pepper, *The Boy's Playbook of Science* (London: Routledge, Warne, and Routledge 1860), 318.

Cassel's Complete Book of Sports and Pastimes (1896), another "book for boys,"[99] even suggested the boys could simply paint their peg tops different colors to observe the effects of color mixing, making the connection between the color top and boys' peg tops explicit.[100]

I certainly do not want to suggest that men were the only scientific practitioners to spin the color top. While there is no concrete evidence that she spun the color top, one of the principal observers for at least some of Maxwell's work on color was his wife Katherine (née Katherine Dewar), in the early days of their marriage.[101] Her work as observer "K." in Maxwell's "On the Theory of Compound Colours, and the Relations of the Colours of the Spectrum" (1860) comes not from working with the "color top," but from its successor.[102] Maxwell's dissatisfaction with the limitations of his color tops led him to develop a series of 'light boxes' (Figure 3-10): an apparatus he describes – using a confusing mixed metaphor that kept the theme of toys and games – as "like a bagatelle board[103] and a Newtonian telescope with a general Post office receiving box in the front and 2 prisms and a concave speculum behind."[104] This enabled different proportions of primary lights to be combined more precisely. Part of Maxwell's dissatisfaction arose from the fact that the color top only mimicked color mixing through persistence of vision, rather than combining different wavelengths of light. Maxwell's discussion about light boxes also suggests an awareness that the entertaining color top may not have appeared scientific enough. In an 1857 letter to James Forbes, Maxwell mentions that further

[99] *Cassell's Book of In-Door Amusements, Card Games, and Fireside Fun* (London: Cassell, Petter, Galpin, & Co. 1882), iii.
[100] *Cassell's Book of In-Door Amusements*, 434.
[101] Campbell and Garnett, *Life of James Clerk Maxwell*, 315; P. M. Harman, *The Natural Philosophy of James Clerk Maxwell* (Cambridge: Cambridge University Press, 1998), 45.
[102] Maxwell, "Theory of Compound Colours," 1:427.
[103] Bagatelle is like pool, but with pins the balls can bounce off. Some forms, such as billard japonais, are closer to modern day pinball.
[104] Longair, "Maxwell and the Science of Colour," 1693; Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:644. Like Helmholtz, Maxwell also projected different colors onto screens (Maxwell, "Theory of Compound Colours," 1:244).

work on color—attempting to differentiate a "theory of colour" and a "theory of light"—would not be prudent "without a good show of very scientific-looking experiments to back it. Coloured papers and spinning tops though capable of far greater accuracy than most spectrum experiments convey no absolute facts about definite colours."[105] Given tops' association with childhood play, Maxwell had good reason to doubt whether they were sufficiently "scientific-looking." Yet even though Maxwell's interest in the late 1850s shifted to light boxes, he continued to collect observations of color tops from others.[106] Scholars sometimes describe Katherine Maxwell as a check on Maxwell's playfulness. One apocryphal anecdote holds that Katherine once ended an evening out by exclaiming "James, you are beginning to enjoy yourself; it is time to go home!"[107] But Maxwell would likely have been interested in her observations on his color top as well.

Figure 3-10: Photograph of one of Maxwell's light boxes.[108]

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[105] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:571-72.
[106] Maxwell, "Theory of Compound Colours," 1:441.
[107] Mark McCartney, "I Remember Years and Labours as a Tale That I Have Read," in *James Clerk Maxwell: Perspectives on His Life and Work* (Oxford: Oxford University Press, 2014), 293.
[108] "Maxwell's Light Box," P2053, University of Cambridge Digital Library, https://cudl.lib.cam.ac.uk/view/PH-CAVENDISH-P-02053/1. Creative Commons License (CC BY-NC 3.0), https://creativecommons.org/licenses/by-nc/3.0/.

It should be acknowledged that my claim about Maxwell's confidence in female observers is somewhat at odds with Stella Pratt-Smith's recent work on Maxwell's poetry. In his pair of poems titled "Lectures to Women on Physical Science," Maxwell describes how Victorian science might be experienced by a woman. In the first poem, a woman who is criticized for being unable to properly read a mirror galvanometer has her scientific capability questioned by the lecturer. In the second, a female student speaks to an ungendered (but, given the context of the two poems, likely male) "Professor Chrschtschonovitsch," and criticizes his overinvestment in science. In both poems, the female student has her precision critiqued. The first observing man of science tells his student that her failure to "read the scale / Correct" is because "To mirror heaven those eyes were given / And not for methods for precision."[109] Stella Pratt-Smith reads this poem as evidence of Maxwell's interest in questions of gender and science. While she distances the speaker's voice from Maxwell's—in her assertion that it is meant to be a "light-hearted" articulation of common Victorian views—she also presents this as evidence that Maxwell associated lack of precision with women in science.[110] I, however, read the poem somewhat differently. The idea that this is "light-hearted" seems odd given Maxwell's sequel, where it is clear that the lecturer is not only an inept teacher but is also a possible source of violence, as he grabs the student's wrist hard enough to cause her pain. The poem reads to me as a critique of the masculine lecturer, and therefore suggests if anything that one should be wary about believing its assertion that women are incapable of precision. This seems more in line with the role Katherine played as an observer.

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[109] Campbell and Garnett, *Life of James Clerk Maxwell*, 631.

[110] Stella Pratt-Smith, "Boundaries of Perception: James Clerk Maxwell's Poetry of Self, Senses, and Science," in *James Clerk Maxwell: Perspectives on his Life and Work*, ed. Raymond Flood, Mark McCartney, and Andrew Whitaker (Oxford: Oxford University Press 2014), 248.

Of course, not every observer of the color top would have produced the kind of useful experimental data Katherine did. As I noted, light conditions were key in these experiments. When Maxwell brought the top out as a recreation for guests, the most common result would have been that each new observer simply contributed anecdotal evidence supporting Maxwell's assertion about the similarity of most human perception. The best-case scenario would have been that someone so enjoyed playing with the color top that they might reproduce his experiment with their own apparatus. However, Maxwell was also aware that there was a chance that these objects, treated as entertainment, might prompt people to be contented with the simple pleasure of viewing rather than seeking deeper understanding. In a draft of his 1861 lecture "On the Theory of Three Primary Colours"—a Royal Institution lecture in which Maxwell not only demonstrated his color top, but also the first permanent color photograph—he admits that "within the domain of the Physical Sciences many facts have been discovered which may be described and exhibited to an unscientific mind in such a way as to afford great satisfaction but without rendering the mind any more scientific than at first."[111]

In depicting his color top as both a "top" and "teetotum"—associated with toys—and as an "instrument,"[112] Maxwell was able to both practice science which seemed objective and to encourage more observers by appealing to their sense of fun. However, this strategy had risks: not all observers would have been interested in moving past the initial fun or entertainment to deeper understanding. Such risks were probably offset by the attention the 'color top' received as

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[111] James Clerk Maxwell, "Drafts and Notes for Lecture 'On the theory of Three Primary Colours' (SP XXII, SLP 184)," 1847-1879, MS.Add.7655/V/b/22(ii), James Clerk Maxwell: Correspondence and Papers, Cambridge University Library, Cambridge, U.K.
[112] Maxwell, "Manuscript on the Comparison of Colours Using a Spinning Top. 27 February 1855," 1:286.

a toy. Moreover, as I discuss in the next section, this was not the only advantage in choosing a top as an experimental instrument.

V. The Dynamical Top

Maxwell's "dynamical top" was equally important to the rise of Maxwell's scientific reputation in the 1850s. Yet discussion of the dynamical top in scholarship on Maxwell can seem strangely perfunctory. This is an omission humorously made evident in an animation created by Cameron Duguid in 2013 for the National Museum of Scotland. In this short animation, Albert Einstein brings Maxwell to the future to interview him about how the dynamical top works, and yet when the dynamical top comes up, the interview runs out of time before Maxwell can do more than repeat his claim, first made when presenting the dynamical top before the RSE, that "to those who study the progress of exact science, the common spinning-top is a symbol of the labours and the perplexities of men who had successfully threaded the mazes of the planetary motions."[113] What the dynamical top actually *is* and how it functions is not explained. To avoid falling into the same trap, this section aims to answer these questions and correct common misunderstandings about the dynamical top.

Perhaps because this was Maxwell's opening line in his lecture, or perhaps because of the common use of tops as an analogy for planetary motion by nineteenth-century scientific practitioners, the dynamical top is frequently misrepresented as an instrument for modelling the rotation and precession of the Earth.[114] While Maxwell demonstrated for the RSE that it could be

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[113] Cameron Duguid, "James Clerk Maxwell Animated," www.nms.ac.uk/explore-our-collections/stories/science-and-technology/james-clerk-maxwell-inventions/james-clerk-maxwell/james-clerk-maxwell-animated/; Maxwell, "On a Dynamical Top," 1:248.
[114] See Brown, *Poetry of Victorian Scientists*, 35; James Clerk Maxwell Foundation, "Maxwell's Dynamical Top," www.clerkmaxwellfoundation.org/html/dynamical_top_.html.

used for this purpose, he also emphasized that the top's ability to illustrate "astronomical precision" is not its primary function: it was designed for "intricacies far exceeding those of the theory of precession."[115] Emphasizing that astronomical modelling was only one part of the top's function, Maxwell explains that "Precession can be illustrated by the apparatus,"[116] but he describes this type of modeling of the Earth as "far more easily comprehended" than other applications of the top. He repeatedly emphasizes the ease of modeling the earth's precession to highlight what Maxwell believes to be the function of his top, which previous mechanical tops have failed to do due to their lack of adjustments: "to exhibit far more complicated phenomena."[117]

Maxwell was not always so emphatic in drawing attention to the dynamical top's complexity. In a letter sent to his cousin, Henry Clerk, in June of 1856, Maxwell describes the top as "constructed […] to show the rotatory motion of a body nearly but not quite spherical like our earth."[118] The possibility of modelling the earth's rotation clearly was central to the top's invention. In addition, as P.M. Harman has suggested, the dynamical top was proceeded by another, simpler top, described by Maxwell in a February, 1856 letter to his father as a "great top[…] with coloured discs attached."[119] Harman has suggested that this is the top preserved in the Cavendish Laboratory, Cambridge: a wooden sphere which spins around a point near its center of mass, and which has an affixed color disk like the dynamical top, but which does not have the dynamical top's adjustments (Figure 3-11). Again, the spherical shape is a suggestion that the dynamical top emerged from a desire to in some way illustrate the rotation of the earth.

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[115] Maxwell, "On a Dynamical Top," 1:248.
[116] Maxwell, "On a Dynamical Top," 1:259.
[117] Maxwell, "On a Dynamical Top," 1:249.
[118] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1874-1879*, ed. P. M. Harman (Cambridge: Cambridge University Press, 2002), 3:866.
[119] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:384.

The abandonment of the top's spherical shape and the trivialization of its ability to model the earth's movement therefore suggest a process of development shaped by Maxwell's desire for the top to be able to model more complex phenomena.

Figure 3-11: Photograph of Maxwell's wooden dynamical top from 1856, taken by Walter Andrews in 1962 and colorized by Kelvin Fagan in 2016.[120]

It is this complexity which seems to have discouraged scholars from fully investigating the dynamical top's function. As Herbert Goldstein noted in what was, for much of the twentieth century, the standard textbook for classical mechanics, the study of rotatory motion can lead to rather "jabberwockian sounding statement[s]" such as "the polhode rolls without slipping on the herpolhode lying in the invariable plane."[121] Attempts to clarify these terms can be similarly fraught. The polhode is the curve the angular velocity vector traces along the inertia ellipsoid.

[120] Kelvin Fagan, "Maxwell's Dynamical Top," 2016, P2005, University of Cambridge Digital Library, https://cudl.lib.cam.ac.uk/view/PH-CAVENDISH-P-02005/1. Creative Commons License (CC BY-NC 3.0), https://creativecommons.org/licenses/by-nc/3.0/.
[121] Herbert Goldstein, *Classical Mechanics* (Reading, Massachusetts: Addison-Wesley Publishing Company), 207.

The herpolhode is the curve the angular velocity vector traces along the invariable plane. What is the invariable plane? It is, of course, an imagined plane orthogonal to the angular momentum vector. I suspect that scholars have hesitated to take on somewhat advanced physics, to study an apparatus that is, in name, at least, merely a toy. Here, I am omitting much of this mathematical complexity, as understanding the fine details is not essential to understanding what Maxwell is attempting to do with this top.

The complexity that the study of rotational motion could engender was reflected in the complexity of Maxwell's device. While Maxwell emphasized the simplicity and reproducibility of his color top, he also emphasized that the dynamical top was a serious piece of manufacturing which had to be handled with care. In his article "On a Dynamical Top" (1857), he notes that "the first attempt at spinning rapidly […might] end in the destruction of the top, if not of the table on which it is spun."[122] All the more care was required because of the price of these tops. In 1858, when Maxwell commissioned four from Smith and Ramage (at Forbes's request) for different universities, they cost £3 3s each, or around £1800 altogether today, according to National Museums Scotland.[123] For comparison, Maxwell's salary in his first year as a professor at Marischal College, from 1856-1857, was £382 4s.[124] Assuming Maxwell's salary stayed relatively constant for the four years he held this position, all 4 dynamical tops would have been roughly 3.3% of Maxwell's yearly salary. They dynamical top could be even more expensive when ordered from other instrument makers. A dynamical top sold by Harvey and Peak, instrument makers of Beak Street, London, in 1885 cost six guineas, or £6 6s.[125]

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[122] Maxwell, "On a Dynamical Top," 1:259.
[123] "James Clerk Maxwell's Dynamical Top," National Museums Scotland, www.nms.ac.uk/explore-our-collections/stories/science-and-technology/james-clerk-maxwell-inventions/james-clerk-maxwell/dynamical-top/; Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:604.
[124] James S. Reid, "James Clerk Maxwell's Scottish Chair," *Philosophical Transactions of the Royal Society A* 366 (2008): 1664.
[125] Roger C. Clark, "Maxwell's Dynamical Top," James Clerk Maxwell Foundation.

What connects the dynamical top to the color top is that they were both instruments of visualization. Campbell and Garnett describe the dynamical top as an instrument for "illustrating *Poinsot's Theorie Nouvelle de la Rotation des Corps [1834]*."[126] Louis Poinsot argued that the early nineteenth-century method of dealing with the motion of rotating bodies through long calculations was inefficient: "We may be able, by means of calculations […] to determine the place of the body at the end of a given time; but we do not see at all how it arrives there. We are totally unable to keep it in view and to follow it, as we might wish, with our eyes, during the whole course of its rotation."[127] Rotating bodies presented a challenge to both mental and visual perception: there was no easy way of visualizing their motion in the mind, nor could their motion be followed by the eye. Poinsot's contribution was to the first problem: his new theory of rotatory motion demonstrated how, by focusing on what Maxwell termed "appropriate ideas,"[128] the complex formulas of rotation could be replaced with simpler geometrical problems.

In particular, what is today taught as the "Poinsot construction" focuses on only four qualities of rotating force free rigid bodies: the angular velocity vector (or what Maxwell called the "instantaneous axis of rotation") $\vec{\omega}$, the angular momentum vector $\vec{L}$, (or as it was known to Maxwell, the "invariable axis"), the kinetic energy T, and the moments of inertia $I_1, I_2,$ and I_3.[129] In short, angular velocity refers to the rate of change of a rotating object's position about some point. The moment of inertia is related to an object's resistance to changes to its angular acceleration. Angular momentum is the rotational analog to linear momentum and is conserved unless an outside force acts on the object. Without external forces the kinetic energy of a rotating

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126 Campbell and Garnett, *Life of James Clerk Maxwell*, 499.
127 Louis Poinsot, *Outlines of a New Theory of Rotatory Motion* (Cambridge: R. Newby), 2-3.
128 Maxwell, "On a Dynamical Top," 1:250.
129 Stephen T. Thornton and Jerry B. Marion, *Classical Dynamics of Particles and Systems* (Belmont, California: Brooks/Cole), 447. For clarity I am here adapting Poinsot and Maxwell's variables and terminology into more modern nomenclature.

object is also a constant. If an object is freely rotating (is not being acted upon by an outside force) and rotates around an axis known as a "principal axis of inertia," the equations for the rotating object's motion can be greatly simplified. Poinsot's insight was to realize that the motion of a rotating object depends only on the moments of inertia. Any two bodies which have the same moments of inertia will move in exactly the same way. Thus, no matter what the real shape of a rotating body is, one can mentally replace it with an equivalent ellipsoid and determine its motion using much simpler geometry. For instance, a typical application of the Poinsot construction is to geometrically represent the movement of $\vec{\omega}$ for different moments of inertia. If a freely rotating object has moments of inertia $I_1 < I_2 < I_3$, solutions for $\vec{\omega}$ can be represented as the intersection of two ellipsoids, and one finds that the object will spin in a stable manner only about principal axes I_1 and I_3. Figure 3-12 shows Maxwell's representation of such a situation. The solutions for $\vec{\omega}$ can form closed curves in the right figure and left figure because these represent the solutions for $\vec{\omega}$ in the case of rotation about I_1 and I_3, which Maxwell labels the 'least' and 'greatest' moments of inertia. In the center figure, however, rotation about I_2—which Maxwell refers to as the 'mean axis'—leads to all solutions for $\vec{\omega}$ being hyperbolic. This is the reason why objects like tennis rackets will rotate very smoothly when spun in some directions, but quickly become unstable when spun otherwise.

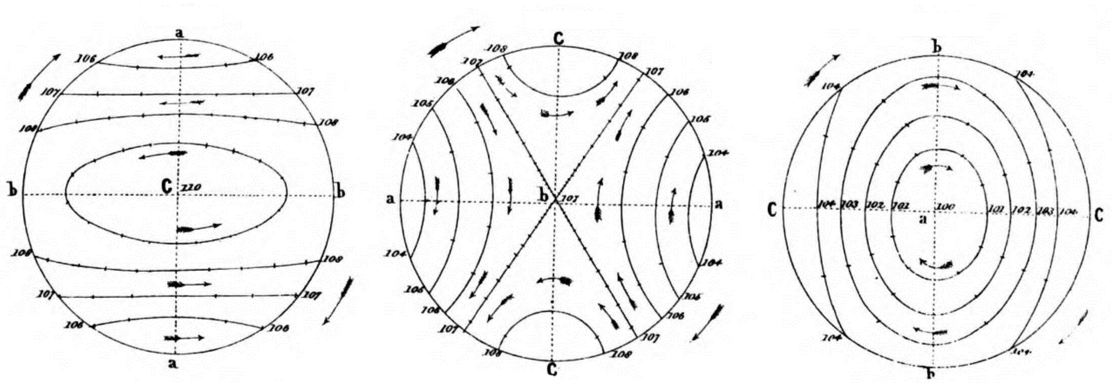

Figure 3-12: Conic sections about various principal axes of inertia in “On a Dynamical Top” (1857)[130]

The issue of how natural phenomena were represented—in the mind, in print, or in material models—was key to Maxwell.[131] Tait suggested that Maxwell’s habit “of constructing a mental representation of every problem,” rather than relying on symbols, was “one of the chief secrets of his wonderful success as an investigator.”[132] This was no doubt the reason why Poinsot’s construction appealed to Maxwell: as he put it, it allowed him to avoid the “very repulsive mass of calculations […] by devoting a little attention to the mechanics and geometry of the problem before entering on the discussion of the equations.”[133] The role of the dynamical top was to go still further. Maxwell had described Poinsot’s work as allowing “ideas” (by which Maxwell means comprehensible “geometrical images”) to “take the place of symbols” (by which Maxwell means mathematical signs which are, in his view, too often removed from the physical phenomena they represent)[134]; the dynamical top would allow one to take these ideas and make them visible.

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[130] Maxwell, “On a Dynamical Top,” 1:263.
[131] Gillian Beer, *Open Fields: Science in Cultural Encounter* (Oxford: Clarendon Press), 297.
[132] Peter Guthrie Tait, “James Clerk Maxwell,” 334.
[133] Maxwell, “On a Dynamical Top,” 1:250.
[134] Maxwell, “On a Dynamical Top,” 1:248, 250.

Like Poinsot, Maxwell recognized that the study of rotation was obstructed by the human eye's inability to reliably track rotating objects. For a rotating disc with a fixed axis, such as the color top, it is easy to "see" the direction the vectors $\vec{\omega}$ and $\vec{L}$ point, once they have been defined for the observer, because they are always along the axis of rotation.[135] But for an object like an asymmetrical top, $\vec{L}$ is not typically parallel to $\vec{\omega}$ and both can change direction with respect to the rotating body over time. As Maxwell put it, "when we attempt to follow with our eye the motion of a rotating body, we find it difficult to determine through what point of the *body* the instantaneous axis [$\vec{\omega}$] passes at any time,—and to determine its path must be still more difficult."[136] He initially described the dynamical top as a way of making the location of $\vec{\omega}$ visible, in order to test whether its motions were really those predicted by the Poinsot construction. Testing Poinsot's theory required a "body balanced on its centre of gravity, and capable of having its principal axes and moments of inertia altered in form and position within certain limits," as well as the ability "to make the axle of the instrument the greatest, least, or mean principal axis, or to make it not a principal axis at all."[137] The dynamical top enables these adjustments through a series of horizontal and vertical bolts and a nut that runs along the axis of rotation. However, Maxwell believed its real innovation was the colored disc at the top, an "optical contrivance for rendering visible the nature of the rapid motion of the top," which he described, in an 1856 exhibition of the top before the BAAS, as making visible the instantaneous axis of rotation $\vec{\omega}$.[138]

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[135] To be more precise, the direction of the vectors in these cases is along the axis of rotation and determined by the 'right-hand rule.'

[136] James Clerk Maxwell, "On an Instrument to Illustrate Poinsôt's Theory of Rotation," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press, 1890), 1:246. Emphasis in original.

[137] Maxwell, "On a Dynamical Top," 1:255.

[138] Maxwell, "Instrument to Illustrate Poinsôt's Theory of Rotation," 1:246; Maxwell, "On a Dynamical Top," 1:249.

When he exhibited the top before the Royal Society of Edinburgh (RSE) the following year, Maxwell described its action more accurately, as allowing him to "see the position of the invariable axis of rotation [$\vec{L}$] at any time."[139] Even with the aid of the colored disc, Maxwell had determined that the instantaneous axis was "not so easily observed." $\vec{\omega}$ can revolve about $\vec{L}$ rather rapidly, and if $I_1 \cong I_2 \cong I_3$, $\vec{\omega}$ and $\vec{L}$ are too close together to differentiate. For these reasons, Maxwell concluded that there was no advantage in studying the motion of the angular velocity vector; what his top visualized far more effectively was the motion of the angular momentum vector relative to the body. For a freely rotating object, $\vec{L}$ is constant over time and is stationary in the fixed reference frame. That is, if the top is initially spun about its axle about the vertical, z-axis (e.g., the position of the top in Figure 3-1), $\vec{L}$ will continue to point in this direction even if the top's asymmetry causes it to tilt and $\vec{\omega}$ no longer points in the z-direction. $\vec{L}$ is constant in a fixed reference frame, but it *does* move relative to the rotating body. So, for instance if the top has tilted and the center of rotation for the top—viewed from above—is colored red, $\vec{L}$ is at that moment passing through the red part of the disc.[140] This innovation, and its usefulness in testing Poinsot's theory of rotation, was cited as the grounds for demonstrating the dynamical top before the RSE.[141]

The visualization of $\vec{L}$ allows Maxwell to test the effects of $I_1, I_2,$ and I_3 on the motion of the rotating top. When the center of rotation cycles through the colors in the same direction as the rotation (e.g., red, yellow, green, blue), it indicates that the axle of the top has been set to be the greatest moment of inertia.[142] When the colors cycle in the opposite direction, it indicates that

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139 Maxwell, "On a Dynamical Top," 1:255.
140 For a demonstration of the top in motion, see James Clerk Maxwell Foundation, "Maxwell's Dynamical Top."
141 Maxwell, "On a Dynamical Top," 1:249.
142 Maxwell, "Instrument to Illustrate Poinsôt's Theory of Rotation," 1:247.

the axle has been set to be the least principal moment of inertia. If the axle is set so that the top revolves around the mean moment of inertia, the top will incline more and more until it can no longer spin. By observing the number of times the top revolves in a complete cycle through the colors, one can even determine the ratio of the moments of inertia.[143] Rather than a device for modeling the earth, the dynamical top was therefore designed as a versatile device for testing the rotation of bodies with a variety of parameters, in order to see whether characteristics such as the angular momentum vector, once made visible, would agree with the geometric representations of the object's motion suggested by Poinsot's theory.

VI. "Experiments of Illustration"

As with the color top, there was no necessity in labelling the dynamical top as a 'top.' Tops are not referenced in Poinsot's *Outlines of a New Theory of Rotatory Motion* (1834). By referring to this object as a 'top' Maxwell is once again drawing attention to its value as a toy. He opened his demonstration of the dynamical top to the RSE with explicit reference to tops as "toy[s] of […] youth."[144] As with the color top, the pleasure of playing with and viewing the top also led Maxwell to bring it out as an entertainment for guests (when he was not using it to play pranks on them). Again, these demonstrations likely had the value of encouraging more observations of the top. Maxwell had several versions made by Ramage and distributed to fellow practitioners at other universities, where one imagines they were probably accepted as both useful instruments of study and as fun gifts.[145] But Maxwell's frequent description of the dynamical top as an

[143] Maxwell, "On a Dynamical Top," 1:258.
[144] Maxwell, "On a Dynamical Top," 1:248.
[145] Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:557.

apparatus for "illustration" also points towards another reason why Maxwell may have valued the dynamical top's ability to function as a toy.

For Maxwell, the dynamical top is an instrument for "illustrating the mathematical theory [of Poinsot],"[146], "illustrat[ing] different propositions,"[147] "illustrat[ing…] the alteration of the position of the axis in a body rotating freely about its centre of gravity,"[148] or else "illustrat[ing…] astronomical precession."[149] Maxwell's writings discuss "illustration" in two senses. In the narrower "illustrative method of exposition," illustration is an alternative to processes of reasoning and calculation.[150] To help one grasp a scientific concept or law from one branch of science, one introduces a concept or a law from a different branch of science—one with which the practitioner is "more familiar" and which is "analogous in form"—and directs "the mind to lay hold of that mathematical form which is common to the corresponding ideas in the two sciences, leaving out of the account for the present the difference between the physical nature of the real phenomena."[151] As this does not seem to apply to the dynamical top, it seems that he believes that the dynamical top is illustrative in a different sense: it serves as what Maxwell calls an "experiment of illustration."

Maxwell's second definition of 'illustration,' introduced in his 1861 lecture as a Professor of Natural Philosophy at King's College, London, distinguishes "between experiments of illustration, which, like the diagrams of Euclid, serve merely to direct the mind to the contemplation of the desired subject, and experiments of research, in which the thing sought is a

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[146] Maxwell, "On a Dynamical Top," 1:249.
[147] Maxwell, "Instrument to Illustrate Poinsôt's Theory of Rotation," 1:247.
[148] Maxwell, "On a Dynamical Top," 1:250.
[149] Maxwell, "On a Dynamical Top," 1:248.
[150] James Clerk Maxwell, "Address to the Mathematical and Physical Sections of the British Society. Liverpool, September 15, 1870," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press, 1890), 2:219.
[151] Maxwell, "Address to the Mathematical and Physical Sections of the British Society," 2:219.

quantity, whose value could not be discovered without experiment."[152] As Maxwell clarifies in his 1871 "Introductory Lecture on Experimental Physics," an "experiment of research" principally aims "to measure something which we have already seen," or "to see what happens under certain conditions" if the experimenter is "not yet familiar with the result."[153] In contrast, the experiment of illustration aims not only to direct the mind towards a phenomenon but also to visualize it. By arranging the experiment so that a phenomenon is "brought into prominence, instead of being obscured and entangled among other phenomena, as it is when it occurs in the ordinary course of nature," the experiment of illustration "throw[s] light" upon the scientific idea "so that the student may grasp it."[154]

In addition to defining experiments of research and experiments of illustration, the "Introductory Lecture to Experimental Physics" also hints at a peculiar genealogy for the "experiment of illustration." Maxwell suggests that "we may find illustrations of the highest doctrines of science in games and gymnastics," among other examples of "matter in motion."[155] In his later 1873 lecture "On Faraday's Lines of Force," he goes further, suggesting that recreational activities were likely some of the first experiments of illustration. Maxwell argues that:

> the first true ideas about the reciprocity of force were probably derived from observations on games with balls. In ordinary circumstances, the motions of bodies are affected by so many different causes, that until some exceptionally simple phenomenon presents itself, we do not know what is the right thing to attend to first. As soon, however, as we become acquainted with this more simple phenomenon and we have been put in the right way of looking at it […] then we know in ourselves that we have obtained a key to one department of the mystery of nature. […] Such exceptionally simple phenomena, when purposefully produced, are called illustrative experiments.[156]

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[152] Maxwell, "Inaugural Lecture at King's College, London. October 1860," 669.
[153] Maxwell, "Introductory Lecture on Experimental Physics," 2:243.
[154] Maxwell, "Introductory Lecture on Experimental Physics," 2:242-3.
[155] Maxwell, "Introductory Lecture on Experimental Physics," 2:243.
[156] Maxwell, "Lecture on Faraday's Lines of Force," 2:794.

In other words, games with balls likely led to the first ideas about the reciprocity of force because games are not "ordinary circumstances." The spaces of play often involve delineated rules and attention to small details, as made evident whenever a game stalls over a disagreement over the legitimacy of a player's actions. They can therefore be understood as simplified versions of interactions in the ordinary world which also encourage careful observation. Importantly, Maxwell does not suggest that these ball games provided a full understanding of the reciprocity of force: they only provided the "first true ideas," setting the stage for more rigorous experiments of research later.

Maxwell may have been motivated to understand simple toys as experiments of illustration by William Whewell's argument about the importance of play objects to the formation of geometry. In *The Philosophy of the Inductive Sciences* (1840), Whewell argued that various geometric concepts were inspired by and understood through common objects: "a sphere (*σφαίρα*) was a hand-ball used in games; a *cone* (*κώνος*) was a boy's spinning-top, or the crest of a helmet; a *cylind*er (*κύλινδρος*) was a roller; a *cube* (*κύβος*) was a die."[157] Maxwell, who was quite familiar with Whewell's philosophy,[158] may have been inspired to argue that if these objects prompted understanding of geometric concepts, they may have prompted understanding of physical laws and concepts as well.

Given this understanding of experiments of illustration, it seems likely that Maxwell would have also considered that the first true ideas about rotational motion may have been made apparent through people playing with tops. Even without comprehensive understanding, play with tops can reveal characteristics of rotatory motion which might be less visible in nature, such

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[157] William Whewell, *The Philosophy of the Inductive Sciences, Founded Upon Their History* (London: John W. Parker, 1840), 1:xlix. Emphasis in original.
[158] For more on Maxwell and Whewell's philosophy, see Harman, *Natural Philosophy of James Clerk Maxwell*, 28.

as the fact that objects spinning quickly enough can seem to resist the force of gravity (thanks to conservation of angular momentum). Maxwell may have chosen the label of 'dynamical top' to place his work in this lineage of illustrative experiments. There are numerous examples of nineteenth-century toys which were given unique names, emphasizing their novelty. The thaumatrope, phenakistiscope, zoetrope, and kaleidoscope, for instance, were all nineteenth-century coinages. Yet Maxwell introduced his 'dynamical top' as merely one in a long line of similar objects which children and adults had been playing with for millennia. This classification may be explained if Maxwell understood the 'dynamical top' not as an attempt to turn a toy into a scientific instrument, but as a modification of an apparatus which had been shedding light on the characteristics of rotatory motion for generations.

In his poem on pearies, the young James Clerk Maxwell describes the earliest tops as being objects of endless fascination; "the Roman children […] chased the wooden plaything without end,"[159] no doubt providing ample opportunity to observe and think about rotation, even if mathematical treatments of these devices did not become common until the nineteenth century. By labelling his device as a 'dynamical top,' Maxwell draws a line between these Roman children and the observers of his top, positioning it as both an ordinary and extraordinary object. On the one hand, the 'men of science' for whom Maxwell demonstrated the dynamical top—having likely also chased tops their childhoods—would have considered tops familiar objects, unlikely to surprise them. On the other hand, the long history of chasing tops makes the previously unseen characteristics which the dynamical top sheds light on all the more marvelous. So much time has been spent playing with tops, and yet the dynamical top reveals aspects of rotation, such as the path of the angular momentum vector relative to the rotating body, that had

[159] Maxwell, "Torto Volitans Sub Verbere Turbo Quem Pueri Magno in Gyro Vacua Atria Circum Intenti Ludo Exercent."

not previously been observed by the naked eye. While Maxwell believed that the top as a "symbol of […] labor" had helped to explain "the mazes of planetary motions,"[160] it was the top's function as a symbol of play which made the characteristics of rotatory motion which the dynamical top revealed more astounding.

VII. Conclusion

A century before Maxwell's tops, Jean-Jacques Rousseau gave a famous dismissal of toys in *Emile* (1763), his treatise on education. According to Rousseau, when a child "whips a top, he is increasing his strength by using it, but without learning anything."[161] Maxwell's play and work with his color top and dynamical top could be said to be a strong refutation of Rousseau's claim: it seems that one can not only learn from a top, but that it can be an instrument for constructing new knowledge. Or, given the ambiguity of the term 'top,' perhaps it is more accurate to say that Maxwell demonstrated that one could do so with a rotating object that one is willing to classify as a 'top.' As I've argued, choosing a label which allowed these rotatory apparatuses to be both toys and scientific instruments benefitted Maxwell's scientific practice.

Maxwell's use of tops also raises questions about whether scholars should reconsider other models and instruments which have not typically been associated with Maxwell's scientific toys in the context of Maxwell's playfulness. Maxwell's student and later fellow physicist Horace Lamb recalled that when hosting guests, Maxwell "had two toys which he would sometimes bring out to entertain fresh visitors,"[162] his dynamical top and the ophthalmoscope

[160] Maxwell, "On a Dynamical Top," 1:248.
[161] Jean-Jacques Rousseau, *Émile, ou de l'éducation* (Francfort: n.s., 1762), 197.
[162] Qtd. in Brown, *The Poetry of Victorian Scientists*, 35.

which he invented and enjoyed demonstrating on himself and his dog.[163] What seem to be two quite different technologies are now connected by the recognition that Maxwell also saw tops as a technology associated with perception and visualization. Although it lacked extant associations with play, Lamb is right in recognizing that in this context the ophthalmoscope too seems like it might be a toy.

As another example, one might take Maxwell's thermodynamic surface (Figure 3-13). This clay (and later plaster) surface—which models a three-dimensional graph (with axes representing volume, entropy, and energy) representing the behavior of an imaginary, water-like substance (one which expands as it freezes) in its solid, liquid, and gaseous states[164]—aims to visualize something which previously had only mental and geometrical representation, just as the dynamical top does. Moreover, Maxwell being Maxwell, the history of the thermodynamic surface also has an element of play. As Cargill Gilston Knott shared in 1907, "copies of this model were distributed by Maxwell with a certain amount of playful mystery, for each recipient thought that he was the happy possessor of one of (at most) three. The writer knows of six at least, and possibly there are more."[165] Of the six Knott knew about, five have been discovered: others went to Gibbs, to Tait, to Maxwell's student George Chrystal, and to physicist Thomas Andrews in Belfast.[166] But does this mystery suggest that Maxwell created this model in play, and if it does, does it suggest scholars should be more open to considerations of even models like this as 'toys' which bring pleasure and should be played with?

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[163] For more on Maxwell's development of the ophthalmoscope, see Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, 1:304.
[164] James Clerk Maxwell, "James Clerk Maxwell's Thermodynamic Surface," National Museums Scotland.
[165] Cargill Gilston Knott, "The Scientific Work of Willard Gibbs," *Nature* 75 (1907): 361.
[166] James Clerk Maxwell, "James Clerk Maxwell's Thermodynamic Surface."

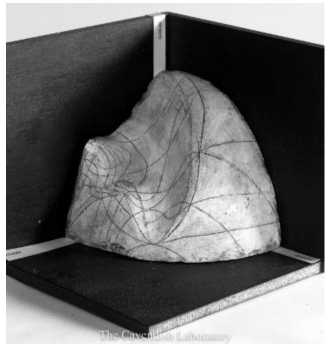

Figure 3-13: Photo (taken by Walter Andrews) of Maxwell's model of Gibbs's thermodynamic surface of water (1876).[167]

Despite the frequent assumption that Maxwell's toys influenced his scientific work, the most one can do is speculate about the nature of this influence. In a 1931 volume of essays, J. J. Thomson suggested that there was "no doubt" that Maxwell's "great skill" with the diabolo had "led him to the construction of his dynamical top,"[168] but the truth is that one cannot be certain of this. Even Campbell and Garnett, who frequently suggest such connections, concede that "of the problems suggested to him [Maxwell] by the devil on two sticks we have no account."[169] Similarly, I cannot know with absolute certainty what value Maxwell ascribed to the recreational function of his tops: whether this was just an incidental use, or an association he consciously cultivated. In this chapter, I have suggested two ways in which Maxwell may have benefitted from working with 'tops.' First, objects of fun may have attracted more observers and encouraged them to build or commission their own versions of these instruments. And second, the 'top,' as part of a history of toys which made physical phenomena perceivable, might be better able to act as an "experiment of illustration." But Maxwell did not need to have a

[167] Walter Andrews, "Maxwell's Model of Gibbs's Thermodynamic Surface of Water (1876)," 1962, P16, University of Cambridge Digital Library, https://cudl.lib.cam.ac.uk/view/PH-CAVENDISH-P-00016/1. Creative Commons License (CC BY-NC 3.0), https://creativecommons.org/licenses/by-nc/3.0/.
[168] J. J. Thomson, "James Clerk Maxwell," in *James Clerk Maxwell: a Commemoration Volume, 1831-1931* (Cambridge: Cambridge University Press, 1931), 6.
[169] Campbell and Garnett, *Life of James Clerk Maxwell*, 499.

conscious justification for his choice of ‘tops’ to receive this benefit. Perhaps it is simpler than this. Perhaps Maxwell simply desired the “liberty and play” he refers to in his poem on pearies: the freedom to have fun in his scientific practice.[170] Regardless of Maxwell’s intentions, it is clear that despite the ‘toy’ being defined in Johnson’s *Dictionary* as “a thing of no value,”[171] in Maxwell’s hands toys were anything but useless.

[170] Maxwell, “Torto Volitans Sub Verbere Turbo Quem Pueri Magno in Gyro Vacua Atria Circum Intenti Ludo Exercent.”
[171] Johnson, *A Dictionary of the English Language* (1768).

Chapter 4 – Maxwell's Demon, Kelvin's Cricket Bats: Playful Absurdity in Thought Experiments

I. Introduction

On December 11th, 1867, James Clerk Maxwell wrote a letter to his friend and fellow physicist, Peter Guthrie Tait.[1] In this letter, Maxwell imagined a being capable of reversing the seemingly universal tendency for thermal energy to dissipate: a tendency German physicist Rudolf Clausius had recently labelled as "entropy." Four years later, Maxwell's thought experiment was shared with the public in his *Theory of Heat* (1871):

> If we conceive a being whose faculties are so sharpened that he can follow every molecule in its course, such a being, whose attributes are still as essentially finite as our own, would be able to do what is at present impossible to us… [T]he molecules in a vessel full of air at uniform temperature are moving with velocities by no means uniform... Now let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being, who can see the individual molecules, opens and closes this hole, so as to allow only the swifter molecules to pass from A to B, and only the slower ones to pass from B to A. He will thus, without expenditure of work, raise the temperature of B and lower that of A, in contradiction to the second law of thermodynamics.[2]

Tait forwarded Maxwell's letter to Sir William Thomson, First Baron Kelvin (a figure who will be referred to as "Kelvin"—sometimes anachronistically—for the remainder of this chapter), and Maxwell shared his thought experiment directly with Kelvin in a letter on January 16th, 1868.[3] Over the next few decades, Kelvin made several changes to Maxwell's thought experiment in his

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[1] James Clerk Maxwell, "Letter to Peter Guthrie Tait. 11 Dec. 1867," 1867, MS.Add.7655/I/b/8, James Clerk Maxwell: Correspondence and Papers, University of Cambridge, Cambridge, U.K.
[2] James Clerk Maxwell, *Theory of Heat* (London: Longmans, 1871), 308-09.
[3] James Clerk Maxwell, "Letter to William Thomson. 16 January 1868," in *The Scientific Letters and Papers of James Clerk Maxwell: 1874-1879*, ed. P. M. Harman (Cambridge: Cambridge University Press, 2002).

correspondence and publications. I argue that the versions of the Maxwell's Demon thought experiment created by Maxwell and Kelvin demonstrate the value of playfulness in thought experiments.

Kelvin's first published changes appeared six years after receiving the letter. In a piece on the "Kinetic Theory of the Dissipation of Energy" (1874), Kelvin imagines how energy might be diffused in a bar of metal and introduces what he labels as "an army of Maxwell's 'intelligent demons'" to prevent the energetic molecules from diffusing.[4] He notes that demons like this could separate the hot from the cold part of a metal bar in the same way that they could separate the hotter and colder molecules in a vessel filled with gas. The reader is asked to "suppose the weapon of the ideal army to be a club, or as it were, a molecular cricket-bat." Each of these soldiers is meant to "keep as nearly as possible to a certain station, making only such excursions from it as the execution of his orders requires… guard[ing] his allotment, turning molecules back or allowing them to pass to either side, according to definite orders."

Five years later, Kelvin personifies the "demon" more explicitly in his article on "The Sorting Demon of Maxwell" (1879). He insists that the demon is "a being with no preternatural qualities, and differs from real living animals only in extreme smallness and agility."[5] The only skill that the demon has which humans do not is that he "can at pleasure stop, or strike, or push, or pull any single atom of matter, and so moderate its natural course of motion." This allows the demon to "reverse the natural dissipation of energy" and "'sort' the molecules in a solution of salt or in a mixture of two gases. In addition, the Demon Kelvin asks his reader to imagine is also morphologically similar to a human being: "Endowed ideally with arms and hands and fingers—

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[4] William Thomson, "Kinetic Theory of the Dissipation of Energy," *Nature* 9 (1874): 442.
[5] William Thomson, "The Sorting Demon of Maxwell," *Nature* 20 (1879): 126.

two hands and ten fingers suffice—he can do as much for atoms as a pianoforte player can do for the keys of the piano."

Kelvin's attempts to emphasize Maxwell's ownership of the thought experiment, through references to '*Maxwell's* Demon' and 'the sorting Demon *of Maxwell*,' are ultimately misleading. In "Kinetic Theory of the Dissipation of Energy" (1874), Kelvin inaccurately claims that "The definition of a 'demon,' *according to the use of this word by Maxwell,* is an intelligent being endowed with free will, and fine enough tactile and perceptive organization to give him the faculty of observing and influencing individual molecules of matter."[6] But as Maxwell insisted in a note "Concerning Demons" he sent to Tait, it was actually Kelvin who named the Demon.[7] Perhaps recognizing his error, Kelvin's later discussion of the Demon implies, but does not fully cop to, the fact that Kelvin coined the term. In "The Sorting Demon of Maxwell," Kelvin confidently clarifies his use of the term "Demon":

> [t]he word 'demon,' which originally in Greek meant a supernatural being, has never been properly used to signify a real or ideal personification or malignity. Clerk Maxwell's 'demon' is a creature of imagination having certain perfectly well-defined powers of action, purely mechanical in their character, invented to help us to understand the 'Dissipation of Energy' in nature.[8]

The fact that this thought experiment is known as "Maxwell's Demon" to this day suggests that despite the possessive, Maxwell's Demon does not really belong to Maxwell. Kelvin's contribution to the thought experiment was equally important.

In this chapter, I explore archival and published writings on this thought experiment from a variety of Victorian physicists to argue that both Maxwell and Kelvin personified the Demon in

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[6] Thomson, "Kinetic Theory of the Dissipation of Energy," 442. Emphasis added.
[7] See James Clerk Maxwell, "Notes 'Concerning Demons' and 'Concerning a Molecular Aether' (SLP 547, 1 f.)," 1849-1878, MS.Add.7655/V/i/11A, James Clerk Maxwell: Correspondence and Papers, University of Cambridge, Cambridge, U.K.
[8] Thomson, "The Sorting Demon of Maxwell," 126.

ways that may seem absurd, often at the risk of distracting readers or adding ambiguity to the thought experiment. As in Chapter Two, I am using the word absurd here both to refer to playfulness and to discordance. Maxwell and Kelvin's personification of the Demon is incongruous with the thought experiment's ostensible goals. Why humanize the Demon when the thought experiment is meant to demonstrate chance? I argue that some of the details Maxwell and Kelvin include can be explained by their desire (whether conscious or unconscious) for the Maxwell's Demon thought experiment to act as what I call a "fiction of escape," providing hope to counteract Victorian fears about entropy. However, I explain that I found the real value of these absurd elements in my attempt to explain them. The playful absurdity of this thought experiment encourages readers to reconsider it multiple times, in the hopes of making sense of some of its ambiguities. Maxwell's Demon illustrates the ways in which playful absurdity in thought experiments can be a tool for fostering lack of certainty and encouraging reconceptualization.

II. Kelvin, Maxwell, and Fictions of Escape

To understand the details of the Maxwell's Demon thought experiment, it is first important to discuss the history of Maxwell and Kelvin's contributions to the developing science of thermodynamics. Kelvin became one of the principal figures bringing thermodynamic ideas to British audiences in the 1850s. He presented a series of papers "On the Dynamical Theory of Heat" to the Royal Society of Edinburgh (RSE), which outlined the basic principles of the new science of thermodynamics.[9] In these papers, he accepted James Prescott Joule's proposal that

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[9] Iwan Rhys Morus, "'A Dynamical Form of Mechanical Effect': Thomson's Thermodynamics," in *Kelvin: Life, Labours, and Legacy*, ed. Raymond Flood, Mark McCartney, and Andrew Whitaker (Oxford: Oxford University Press, 2008).

heat was in some way equivalent to mechanical motion.[10] For example, in a steam engine, thermal energy was transformed into mechanical motion, while mechanical motion could also produce heat through friction. Adapting the work of Sadi Carnot, Kelvin also argued that "the mechanical effect derivable from a given quantity of heat by means of a perfect engine in which the range of temperatures is infinitely small, expresses truly the greatest effect which can possibly be obtained in the circumstances; although it is in reality only an infinitely small fraction of the whole mechanical equivalent of the heat supplied; the remainder being irrecoverably lost to man, and therefore 'wasted,' although not *annihilated*."[11] In other words, there was no such thing as a perfectly efficient engine. Today, this is known as the Kelvin-Planck statement. Any process in which heat is transformed into mechanical motion is going to "waste" some energy. And because heat *must* flow from a warmer body to a colder one, in any closed system (any system which is not exchanging energy with matter outside the system) some energy becomes irretrievable. Once a closed system is at thermal equilibrium, heat can no longer produce motive power.

As an example, consider a person drinking tea in a closed room which serves as an isolated system: nothing can enter or exit it. Heat from the tea will dissipate from the hot cup to the cooler environment, some energy being transferred to the drinker's hands, some remaining in the liquid, and some radiating into the air around them. The existence of a temperature gradient means that in the initial stages the energy of the tea could be used to create mechanical motion. For instance, heat rising from the cup could be used as a heat source for a small steam engine. However, once the energy has diffused into the room and the tea has cooled to room temperature,

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[10] William Thomson, "On the Dynamical Theory of Heat, with Numerical Results Deduced from Mr Joule's equivalent of a Thermal Unit," *Transactions of the Royal Society of Edinburgh* 20 (17 March 1851): 262.
[11] Thomson, "On the Dynamical Theory of Heat," 271. Emphasis in original.

that thermal energy has become useless. There is nothing cooler in the room for the heat to flow into, and as a result it cannot be used to move an engine. Because localized heat always dissipates and temperatures always approach thermal equilibrium, this means that any closed system will eventually reach a point at which heat can no longer be used in this way. In 1865, Clausius termed this tendency towards the dissipation of energy as *entropy* (after *tropos* or transformation) and stated that "the entropy of the universe tends towards a maximum."[12]

These two ideas – that thermal energy can transform into mechanical motion and that, in that transformation, some portion of the energy tends to be wasted -- eventually developed into the first two laws of thermodynamics. First, the various forms of energy (e.g., thermal, electric, kinetic, etc.) can change form, but energy can never be created or destroyed. Second, the entropy of a closed system tends towards a maximum. This second law can be alternatively stated as a law that useful energy tends to dissipate.

Historian P. M. Harman notes that in Kelvin's research on the dissipation of energy, he specifically avoided suggesting how the mechanical model of thermal processes might function.[13] However, other thermodynamicists in the 1840s were already theorizing that heat might be related to or even equivalent to the average kinetic energy of the individual molecules within a substance.[14] Joule had justified his thinking about the mechanical equivalence of heat by arguing that heat itself was "a state of motion among the constituent particles of bodies."[15] It soon became apparent that gases comprised of molecules which were, on average, moving

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[12] Rudolf Clausius, "On the Second Fundamental Theorem of the Mechanical Theory of Heat; a Lecture delivered before the Forty-first Meeting of the German Scientific Association, at Frankfort on the Main, September 23, 1867," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 35 (June 1868): 419.
[13] P. M. Harman, *Energy, Force, and Matter: The Conceptual Development of Nineteenth-Century Physics* (Cambridge: Cambridge University Press, 1982), 5.
[14] Harman, *Energy, Force, and Matter*, 37.
[15] James Prescott Joule, "On the Changes of Temperature produced by the Rarefaction and Condensation of Air," *Philosophical Magazine* 26 (May 1845): 381.

quickly, and hence had high kinetic energy, were of higher temperature than gases with molecules which were, on average, moving more slowly.

Enter James Clerk Maxwell. I alluded to the relationship between Kelvin and Maxwell in the previous chapter, as Kelvin was one of the observers of Maxwell's spinning tops.[16] Kelvin had long served as one of Maxwell's advisors. Kelvin requested Maxwell's help in the BAAS's annual meeting in Edinburgh in 1850,[17] and Maxwell cited Kelvin as an inspiration for his research on electricity in his *Treatise on Electricity and Magnetism* (1873).[18] Maxwell was also quite familiar with Kelvin's contributions to heat and energy, as he informed Lewis Campbell in 1862 that Joule and Thomson were two of the preeminent experts on conservation of energy.[19]

Maxwell was therefore a fitting figure to help redefine the second law of thermodynamics in statistical terms, as he did in 1859. This was the year in which Maxwell broke new ground with his presentation on "Illustrations on a Dynamical Theory of Gases," delivered at a Meeting of the BAAS. This talk, published in the *Philosophical* Magazine in 1860, derived the properties of a gas from the statistical spread of molecular velocities within the gas.[20] In treating gases in this way, Maxwell moved the problem outside the framework of traditional Newtonian mechanics. Because gases contained millions upon millions of molecules, treating the problem of molecules' energies individually was not practical. Maxwell instead utilized statistics and probability. At first, this was considered a mere convenience, to be used where other methods were impractical. But Maxwell soon began to argue that statistics was in fact the best method for investigating all properties of gases. With this dynamical theory, Maxwell was able to derive

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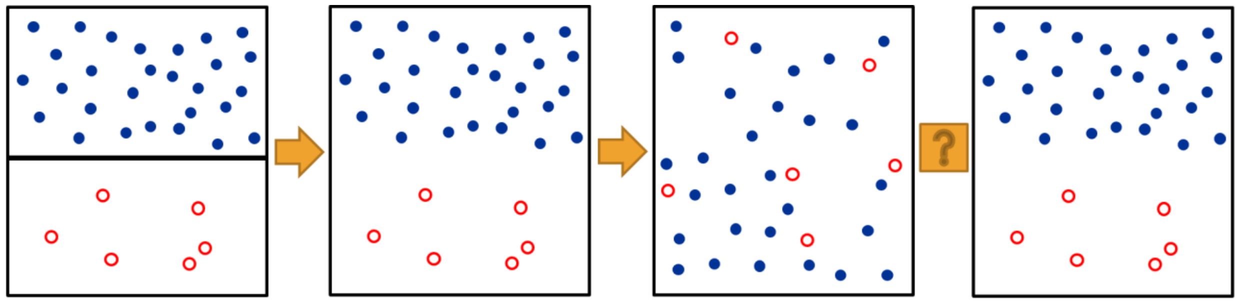
[16] Lewis Campbell and William Garnett, *The Life of James Clerk Maxwell* (London: Macmillan, 1882), 212.
[17] Campbell and Garnett, *Life of James Clerk Maxwell*, 144.
[18] James Clerk Maxwell, *A Treatise on Electricity and Magnetism* (Oxford: Clarendon Press, 1873), x.
[19] Campbell and Garnett, *Life of James Clerk Maxwell*, 335.
[20] James Clerk Maxwell, "Illustrations of the Dynamical Theory of Gases.--Part I. On the Motions and Collisions of Perfectly Elastic Spheres," *Philosophical Magazine* 19 (Jan. 1860).

many of the observed properties of gases and explain the interchange of heat and the kinetic energy described by the first law.[21] Most importantly for the purposes of this chapter, Maxwell suggested that increasing entropy could be considered a statistical law, equivalent to recognizing that it is very *probable* that heat energy will tend to dissipate into unusable forms.

This statistical understanding of entropy is illustrated in Figure 4-1. In this figure, a vessel initially contains two gases at different temperatures, which are initially separated. The red circles represent more energetic molecules that are moving at a higher velocity. The solid blue circles represent less energetic molecules that are moving more slowly. As a result of these molecules' kinetic energies, the section of the vessel in the top left is interpreted, at the macroscopic level, as being at a higher temperature than the section in the bottom left because temperature is related to the average kinetic energy of the system. When the separation between the two parts of the vessel is removed, it is *probable* that the molecules will spread out evenly throughout the vessel, since there are no longer any walls to stop them. This allows the more energetic molecules to become mixed up with the less energetic molecules. To the macroscopic viewer, who cannot see the individual molecules, it would appear that heat has flowed from the hotter gas to the cooler one, resulting in a temperature that is somewhere between the two gases. This explained why earlier thermodynamicists had observed that heat always seemed to flow from hot to cold. This illustration also demonstrates that it is extremely *improbable* that the molecules will sort themselves out by temperature again. And without a temperature differential, thermal energy cannot be used to do any further work in this system.

[21] Matthew Stanley, "The Pointsman: Maxwell's Demon, Victorian Free Will, and the Boundaries of Science," *Journal of the History of Ideas* 69, no. 3 (2008).



(a) Vessel divided into two sections. The bottom contains more energetic gas molecules (red circles), which on the macroscopic level means higher temperature. The top contains less energetic gas molecules (solid blue circles), which on the macroscopic level means lower temperature.

(b) Division between the two parts of the vessel is removed.

(c) It is likely that the molecules will spread out in the vessel, which on the macroscopic level is interpreted as heat from the hotter section dissipating into the colder section.

(d) It is very **unlikely** that that the molecules would spontaneously sort themselves out again, without some kind of external work being done.

Figure 4-1: Illustration that the observation that heat energy tends to dissipate into unusable forms is a statistical law.

Kelvin's interest in the irreversibility of energy dispersion led him to imagine the limit cases for that dispersion in some of his earliest published writings on heat. In "On the Dynamical theory of Heat" (1851), Kelvin imagines "a self acting [*sic*] machine [which] might be set to work and produce mechanical effect by cooling the sea or earth, with no limit but the total loss of heat from the earth and sea, or, in reality, from the whole material world."[22] He points out that such a machine would be impossible because "It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects." In other words, once heat has been dispersed such that the internal temperature of the engine can no longer be made higher than the ambient temperature, the machine would no longer function. There would be, therefore, a

[22] Thomson, "On the Dynamical Theory of Heat," 265.

minimum temperature such a machine could bring the earth to, at which point it would no longer be able to cool the earth further or perform.

In papers published over the next decade, Kelvin extended his scope beyond the planetary. In "On the Universal Tendency in Nature to the Dissipation of Mechanical Energy" (1852), Kelvin observes that energy is not only wasted in human activities; it is a "universal tendency." He arrives at three sobering conclusions:

> 1. There is at present in the material world a universal tendency to the dissipation of mechanical energy.
> 2. Any restoration of mechanical energy, without more than an equivalent of dissipation, is impossible in inanimate material processes, and is probably never effected by means of organized matter, either endowed with vegetable life or subjected to the will of an animated creature.
> 3. Within a finite period of time past, the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted, unless operations have been, or are to be performed, which are impossible under the laws to which the known operations going on at present in the material world are subject.[23]

"On the Mechanical Energies of the Solar System," published in the *Philosophical Magazine* in December of 1854, and "On the Age of the Sun's Heat" (1862) furthered these pessimistic predictions. Although the former does suggest that the sun may regain some energy from meteors, it posits that "The energy [of the sun]—that of light and radiant heat—thus emitted, is dissipated always more and more widely through endless space, and never has been, probably never can be, restored to the sun, without acts as much beyond the scope of human intelligence"[24] and concludes (incorrectly) that "sunlight cannot last as at present for 300,000 years."[25] Similarly, "On the Age of the Sun's Heat" (1862) argues that the universe is headed

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[23] William Thomson, "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy," *Proceedings of the Royal Society of Edinburgh* 3 (19 Apr. 1852): 141-2.
[24] William Thomson, "On the Mechanical Energies of the Solar System," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 8 (Dec. 1854): 410.
[25] Thomson, "Mechanical Energies of the Solar System," 429. Kelvin was of course unfamiliar with radioactivity or nuclear fusion. Current estimates of the lifespan of the sun theorize that the sun will take another five billion years to transition into a red

towards “a state of universal rest and death, if the universe were finite and left to obey existing laws”[26] and suggests that “inhabitants of the earth cannot continue to enjoy the light and heat essential to their life, for many million years longer, unless sources now unknown to us are prepared in the great storehouse of creation.”[27] As American historian Henry Adams put it in 1910, “this young man of twenty-eight thus tossed the universe into the ash-heap.”[28]

The pessimistic prediction must have struck a chord, as many others echoed the idea that the universal tendency to the dissipation of energy would eventually lead to a state known as heat death. For instance, William John Macquorn Rankine took Kelvin’s idea of a universal tendency towards the dissipation of energy and used it to reflect on a possible final condition for the universe in “On the Reconcentration of the Mechanical Energy of the Universe” (1852). In this account, he asserts that if the second law of thermodynamics is true, eventually “all matter will be at the same temperature[…] so that there will be an end of all physical phænomena.”[29] Similarly, Clausius, in a lecture delivered before the 41st meeting of the German Scientific Association on September 23, 1867 stated that “The more the universe approaches this limiting condition in which entropy is a maximum, the more do the occasions of further changes diminish; and supposing this condition to be at last completely attained, no further change could evermore take place, and the universe would be in a state of unchanging death.”[30]

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giant (although the earth will be overcome by the sun’s radius long before this) (K.-P Schröder and Robert Connon Smith, “Distant Future of the Sun and Earth Revisited,” *Monthly Notices of the Royal Astronomical Society* 386, no. 1) and that it will take trillions of years to reach the sort of thermal equilibrium Kelvin calculated (Fraser Cain, “Life of the Sun,” *Universetoday.com*, Space and Astronomy News, 10 March 2012).

[26] William Thomson, “On the Age of the Sun’s Heat,” *Macmillan’s Magazine* 5, no. 29 (March 1862): 388.

[27] Thomson, “Age of the Sun’s Heat,” 393.

[28] Henry Adams, *A Letter to American Teachers of History* (Washington: J. H. Furst, 1910), 4.

[29] William John Macquorn Rankine, “On the Reconcentration of the Mechanical Energy of the Universe,” *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 4 (1852): 359.

[30] Clausius, “Second Fundamental Theorem of the Mechanical Theory of Heat,” 419.

Perhaps the bleakest depiction of heat death comes from Balfour Stewart and Norman Lockyer's "The Place of Life in a Universe of Energy" (1868) because it is the most unflinching about the connection between the death of the universe and the death of individual humans:

> The principle of degradation is at work throughout the universe, not less surely, but only more slowly, than when it combats our puny efforts, and it will ultimately render, it may be, the whole universe, but more assuredly that portion of it with which we are connected, unfit for habitation of beings like ourselves. As far as we are able to judge, the life of the universe will come to an end not less certainly, but only more slowly, than the life of him who pens these lines or of those who read them.[31]

This pessimism is likely primarily the influence of Stewart. All of Stewart's descriptions of heat death are quite bleak. His explanation in *The Conservation of Energy* (1873), published a few years later, is similarly grim, imagining a "great waste-heap of the universe" which will continue to grow until "the whole universe shall be one equally heated inert mass, and from which everything like life or motion or beauty will have utterly gone away."[32]

I dwell on these bleak forecasts to give a sense of how hopeless Victorian thermodynamicists and other Victorians felt in the face of the second law. Ailise Bulfin has called these the "apocalyptic imaginary": "a myriad of entropic images of total war, natural disaster, the fall of civilization and the death of the sun that circulated in late-Victorian culture."[33] Examples of the apocalyptic imaginary outside of thermodynamic literature include William Delisle Hays's *The Doom of the Great City* (1880), John Ruskin's "The Storm Cloud of the Nineteenth Century" (1884), Max Nordau's *Degeneration* (1892), and H. G. Wells's *The Time Machine* (1895). The far-reaching influence of these apocalyptic visions was in part a result of the fact that the sun was more than just an object of study for Victorians: it took on semi-

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[31] Balfour Stewart and J. Norman Lockyer, "The Sun as a Type of the Material Universe. Part II. The Place of Life in a Universe of Energy," *Macmillan's Magazine* 18 (Aug. 1868): 323.
[32] Balfour Stewart, *The Conservation of Energy* (London: Henry S. King & Co., 1873), 153.
[33] Ailise Bulfin, "'The End of Time': M. P. Shiel and the 'Apocalyptic Imaginary,'" in *Victorian Time: Technologies, Standardizations, Catastrophes*, ed. Trish Ferguson (New York: Palgrave Macmillan, 2013), 155.

mythic status in Victorian thermodynamics and Victorian culture more generally.[34]As the source of all life on earth, it was the sun which united poetry, science, and art as a collective endeavor. And with the development of spectroscopy, the sun had become humanity's key to the universe, which for some suggested that the sun was God's way of allowing mankind to know the cosmos. The idea that not only the sun but also the entire universe might someday run down therefore raised frightening questions about the position of humanity in the universe.

As literary scholar Thomas Richards notes, a common response, almost as soon as "scientists formulated a working definition of the entropy law" was "to imagine situations that violated it."[35] For example, Rankine speculated that if there was a boundary at the edge of the universe, energy might eventually be re-concentrated in its center.[36] Others simply attempted to reframe the thermodynamic view of the universe as a positive. Helmholtz embraced this entropic ending as the necessary close to the human story, its "destiny."[37] Borrowing a phrase from Allen MacDuffie, I call these accounts which attempt to escape or reframe heat death "fictions of escape."[38] Most of these fictions were speculative; scientific practitioners did not argue that these were practical solutions or as realistic possibilities. But it is my contention that when models are presented as alternatives to heat death, the ways in which those models are constructed—for

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[34] Gillian Beer, "'The Death of the Sun': Victorian Solar Physics and Solar Myth," in *The Sun is God: Painting, Literature and Mythology in the Nineteenth Century*, ed. J. B. Bullen (Oxford: Clarendon Press, 1989).

[35] Thomas Richards, *The Imperial Archive: Knowledge and the Fantasy of Empire* (London: Verso, 1993), 84.

[36] Rankine, "Reconcentration of the Mechanical Energy of the Universe." Others have also recognized the importance of these boundary conditions of the universe to the second law. Helmholtz suggested a similar solution to Rankine (Harman, *Energy, Force, and Matter*, 68). Clausius saw the universe as a perfectly isolated system (Peter Coveney and Roger Highfield, *The Arrow of Time: A Voyage through Science to Solve Time's Greatest Mystery* (New York: Fawcett Columbine, 1991), 153). In contrast, modern writers such as Assael et al. have asked, if the universe is an isolated system, what is it supposed to be isolated from? (Assael et al., *Commonly Asked Questions in Thermodynamics* (Baca Raton, FL: CRC Press, 2011), 95).

[37] Hermann Helmholtz, "On the Interaction of Natural Forces," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 11 (1856), 516.

[38] Allen MacDuffie, *Victorian Literature, Energy, and the Ecological Imagination* (Cambridge: Cambridge University Press, 2014). Some of my thinking about cosmological models which oppose heat death was prompted by the writing of Helge Kragh (Kragh, *Matter and Spirit in the Universe : Scientific and Religious Preludes to Modern Cosmology* (London: Imperial College Press, 2004); *Entropic Creation : Religious Contexts of Thermodynamics and Cosmology* (Albingdon, U.K. : Routledge, 2008)). My thinking on fictions of escape was also prompted in part by Barri Gold's discussion of "entropic individuals" (Gold, *ThermoPoetics: Energy in Victorian Literature and Science* (Cambridge, MA: MIT Press, 2010), 227).

example, the extraneous details added to thought experiments—reveal the nature of the desired intervention, whether intentional or not.

Such fictions occur in many places in Kelvin and Maxwell's writing, but the most enduring of their fictions of escape has been the thought experiment of Maxwell's Demon. Perhaps this is because the stated goal of this fiction seems relatively modest. Maxwell initially claimed that the function of his version of the thought experiment was merely to "pick a hole… in the 2nd law of [thermodynamics]."[39] As he later clarified in his note "Concerning Demons" (1875), their "chief end" was "To show that the 2nd law of Thermodynamics has only a statistical certainty."[40] What is meant by this is that, in the kinetic theory of molecules put forth by Maxwell, it is extremely unlikely, but not impossible, for the second law to be violated by chance. As Maxwell wrote in a letter to physicist J. W. Strutt in 1870, "The 2nd law of thermodynamics has the same degree of truth as the statement that if you throw a tumblerful of water into the sea, you cannot get the same tumblerful of water out again."[41] Or as Kelvin put it, applying the same logic to the heating of a bar of iron, "it is very improbable that in the course of 1000 years one-half of [a] bar of iron shall of itself become warmer by a degree that the other half… This one instance suffices to explain the philosophy of the foundation on which the theory of the dissipation of energy rests."[42] Spontaneous reversal of entropy was improbable, but not technically impossible.

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[39] James Clerk Maxwell, *The Scientific Letters and Papers of James Clerk Maxwell: 1862-1873,* ed. P. M. Harman (Cambridge: Cambridge University Press, 1995), 2:331.
[40] Maxwell, "Notes 'Concerning Demons' and 'Concerning a Molecular Aether.'"
[41] James Clerk Maxwell, "Letter from Maxwell to John William Strutt, December 6, 1870," in *Maxwell on Heat and Statistical Mechanics: On 'Avoiding All Personal Enquiries' of Molecules*, ed. Elizabeth Garber, Stephen G. Bush, and C. W. F. Everitt (Bethlehem: Lehigh University Press, 1995), 205.
[42] Thomson, "Kinetic Theory of the Dissipation of Energy," 443.

Maxwell's hope that his thought experiment might suggest something more substantial than a mere chance of escaping the second law is signaled in his clarification that the demon is only doing "what is *at present* impossible to us."[43] Maxwell's emphasis on the present state of science is a theme throughout *Theory of Heat* (1871). He uses the phrase "at present" many times, emphasizing that the understanding of heat and the limitations that come with the theory of heat might change. It also appears in the letter in which he introduces Kelvin to his thought experiment, as a possible exception to "the present wasteful world."[44] The implication is that Maxwell's thought experiment can be read as pointing towards some future state in which this type of reversal of entropy might not be impossible. "Present," in "the present wasteful world" can be read as referring either to the *material* world (as compared to a spiritual afterlife) or to a temporal present. In either case, it suggests Maxwell's dissatisfaction with mere statistical possibility and his desire for a more active solution to the second law: a possibility Maxwell and Kelvin left open through their personifications of the Demon.

III. Demons with Jobs

Much of the absurdity of the Maxwell's Demon thought experiment arises from Maxwell and Kelvin's decision to personify the Demon with human attributes. If the only goal was to demonstrate the probabilistic nature of the second law, this could be done by imagining a randomly opening valve, which over very long time periods could produce a situation of decreasing entropy. But, as I discuss in this section, they instead explain the Demon's action

[43] Maxwell, *Theory of Heat,* 308. Emphasis added.
[44] Maxwell, "Letter to William Thomson. 16 January 1868."

through comparison to a series of human careers, which puts absurd and distracting images such as nanoscopic pointsmen into readers' heads and creates ambiguity that might confuse readers.

Historian Matthew Stanley has argued that the thought experiment of Maxwell's Demon emerged from Maxwell's thinking about the relationship between human free will and thermodynamics.[45] Stanley notes that for Maxwell, it was important that the soul be exempt from the laws of thermodynamics. Maxwell wrote a letter to Lewis Campbell in 1862 in which he asserted that "the soul is not the direct moving force of the body. If it were, it would only last till it had done a certain amount of work, like the spring of a watch, which works till it is run down."[46] In other words, the soul could not be creating a physical force that moved the body, or its energy would have to eventually dissipate, in accordance with the second law. Maxwell was also reluctant to say with certainty that human beings could never find a solution to increasing entropy. In his 1870 lecture to the Mathematical and Physical Sections of the BAAS, Maxwell describes the human mind in opposition to the laws of thermodynamics:

> the mind of man is not, like Fourier's heated body, continually settling down into an ultimate state of quiet uniformity, the character of which we can already predict; it is rather like a tree, shooting out branches which adapt themselves to the new aspects of the sky towards which they climb, and roots which contort themselves among the strange strata of the earth into which they delve.[47]

This is, to be sure, not an explicit claim that humanity is exempt from the second law of thermodynamics. But it does suggest Maxwell's belief that, where human free will was involved, the second law could not be taken for granted and the future could be difficult to predict. As Maxwell wrote in the same article, "To us who breathe only the spirit of our own age and know

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[45] Stanley, "The Pointsman."
[46] James Clerk Maxwell, "Letter to Lewis Campbell, April 21 1862," in *The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, ed. P. M. Harman (Cambridge: Cambridge University Press, 1990), 1:711-12.
[47] James Clerk Maxwell, "Address to the Mathematical and Physical Sections of the British Society. Liverpool, September 15, 1870," in *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (Cambridge: Cambridge University Press), 2:226.

only the characteristics of contemporary thought, it is as impossible to predict the general tone of the science of the future as it is to anticipate the particular discoveries which it will make."[48] It could not be assumed that humanity would not someday find a solution to problems like the second law.

Kelvin's writings on thermodynamics reveal the same desire to leave room for human intervention into entropy. In "On the Dynamical Theory of Heat" (1851), Kelvin specifies that "It is impossible, *by means of inanimate material agency*, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects."[49] This leaves open the suggestion that animate creatures may be somehow exempt from the current laws of thermodynamics. Maxwell and Kelvin's desire to leave open the possibility that humans might not be vulnerable to the second law of thermodynamics helps us to understand their personification of the Demon in the thought experiment.

Maxwell's original description of his Demon may at first seem rather sparse. The only illustration that Maxwell included in his letter to Tait to clarify his thought experiment is shown in the upper right-hand corner of Figure 4-2. The division of the vessel is drawn, with A and B labelling the two sides of the vessel and line $\overline{CD}$ marking the boundary that the imagined being would monitor. But not the being itself is not included. Maxwell's notes reveal a fondness for doodling while completing his scientific and mathematical studies,[50] so the exclusion of any illustration of the Demon is notable. A small figure could easily have been sketched at the boundary between A and B. One explanation is that Maxwell intentionally left the visual details

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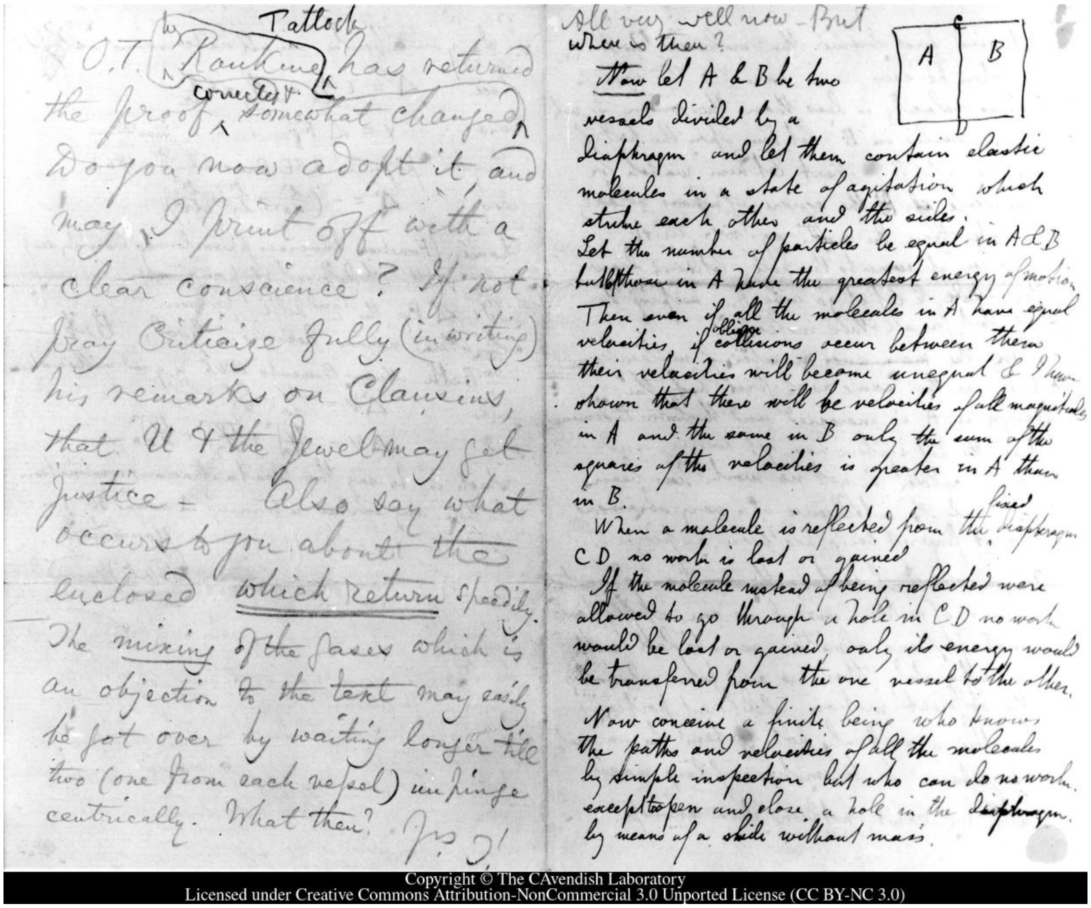
48 Maxwell, "Address to the Mathematical and Physical Sections of the British Society," 2:226-7.
49 Thomson, "On the Dynamical Theory of Heat," 265. Emphasis added.
50 James Clerk Maxwell, "MS.Add.7655/V/i," 1849-1878, MS.Add.7655/V/i, James Clerk Maxwell: Correspondence and Papers, University of Cambridge, Cambridge, U.K.

of the being vague, so that Tait and other readers would not be distracted by the specific form the Demon might take, which would be inconsequential to its actual function.


O.T. Tattock Rankine has returned the proof corrected & somewhat changed. Do you now adopt it, and may I print off with a clear conscience? If not pray Criticize fully (in writing) his remarks on Clausius, that U & the Jewel may get justice. Also say what occurs to you about the enclosed which return speedily. The mixing of the gases which is an objection to the text may easily be got over by waiting longer till two (one from each vessel) impinge centrically. What then? J.S.D!

All very well now – But where is then?

Now let A & B be two vessels divided by a diaphragm and let them contain elastic molecules in a state of agitation which strike each other and the sides. Let the number of particles be equal in A & B but let those in A have the greatest energy of motion. Then even if all the molecules in A have equal velocities, if oblique collisions occur between them their velocities will become unequal & I have shown that there will be velocities of all magnitudes in A and the same in B only the sum of the squares of the velocities is greater in A than in B.

When a molecule is reflected from the fixed diaphragm CD no work is lost or gained.

If the molecule instead of being reflected were allowed to go through a hole in CD no work would be lost or gained, only its energy would be transferred from the one vessel to the other.

Now conceive a finite being who knows the paths and velocities of all the molecules by simple inspection but who can do no work except to open and close a hole in the diaphragm by means of a slide without mass.

Figure 4-2: Photograph of Maxwell's letter to Tait on 11 December, 1867, likely taken in 1931.[51]

Maxwell's letter does, however, include some details characterizing the Demon, even if they are not illustrated in the letter.[52] It is capable of knowledge. It is capable of observation. It is gendered masculine. It is described as "neat-fingered," implying that it may have these appendages. Maxwell did not believe that entropy would actually someday be reversed by a

[51] James Clerk Maxwell, "Letter from Maxwell to Tait on Maxwell's Demon, 11 December 1867," 1931, P92(a), University of Cambridge Digital Library, https://cudl.lib.cam.ac.uk/view/PH-CAVENDISH-P-00092/1. Creative Commons License (CC BY-NC 3.0), https://creativecommons.org/licenses/by-nc/3.0/.
[52] Maxwell, "Letter to Peter Guthrie Tait. 11 Dec. 1867."

microscopic being exactly like this. As historian Jordi Cat has argued, Maxwell used metaphors primarily for illustration rather than explanation, and Maxwell's Demon is no exception.[53] But one can see why the idea of a knowledgeable, masculine figure capable of reversing entropy through careful observation and manipulation of nature would have appealed to Victorian 'men of science.' Maxwell provides in his initial description just enough detail that a reader might envision the Demon as being analogous to a Victorian scientific practitioner. Tait or other scientific practitioners might imagine themselves in that blank space where no Demon is drawn. Maxwell's characterization of the Demon as something similar to a human, in his thought experiment, therefore implies that such actions may not be absolutely outside the realm of human action.

Following Maxwell's lead, Kelvin's formulations describe the Demon as a being even more similar to a human. Kelvin's version of the Demon is "an intelligent being endowed with free will," capable of "voluntary movements."[54] It's "two hands and ten fingers"[55] suggest a humanoid appearance, and Kelvin emphasizes the similarities between this being and other "living animal[s]."

One strategy both Maxwell and Kelvin employed, in some versions of the thought experiment, was comparing the action of Maxwell's Demon to work done as part of human careers. For example, in a letter to J. W. Strutt in 1870, Maxwell compares the Demon to a "doorkeeper" and to a "pointsman on a railway." [56] Kelvin compared the Demon to a pianoforte

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[53] Jordi Cat, "On Understanding: Maxwell on the Methods of Illustration and Scientific Metaphor," *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 32, no. 3 (2001): 486.
[54] Thomson, "Kinetic Theory of the Dissipation of Energy," 442.
[55] Thomson, "The Sorting Demon of Maxwell," 126.
[56] James Clerk Maxwell, "Letter to J. W. Strutt, December 6 1870, *in The Scientific Letters and Papers of James Clerk Maxwell: 1846-1862*, ed. P. M. Harman (Cambridge: Cambridge University Press, 1995). Maxwell also made use of the pointsman analogy in the letter in which he first shared the thought experiment with Kelvin (Maxwell, "Letter to William Thomson. 16 January 1868").

player[57] or a soldier,[58] sometimes as part of an engineer corps[59] and sometimes armed with a cricket bat.[60] The comparison of the Demon's actions to human careers does help to clarify the thought experiment, in some ways. The image of the Demon as a pointsman directing molecules instead of trains or a soldier fighting back molecules instead of enemy combatants does provide readers with a clear image. But it also adds new ambiguities. First, a central aspect of Maxwell's Demon has always been that, as Maxwell put it, it must do "no work"[61] -- must in fact be "incapable of doing work"[62] -- while it sorts the molecules. Maxwell does not mean 'work' in the general sense we discussed in the Introduction to this dissertation. He means 'work' in the new, scientific definition it took on in the nineteenth century, which Maxwell defines as "the product of [a] resisting force and the distance through which that force is overcome" in his *Theory of Heat*.[63] If the Demon were doing work of this type, it would be subject to the second law of thermodynamics, and it would require energy from outside the system to do its sorting. But even though Maxwell's Demon is "incapable of work" in a very specific sense, it is still somewhat absurd to describe the actions of a being "incapable of work" by comparing them to the actions of certain occupations. It makes very little sense to imagine a soldier or a pointsman incapable of work; to be labelled as a soldier or pointsman, they must be defined by the work they do.

Readers may also wonder how far they are supposed to take the comparison. For example, soldiers famously have orders to follow. If the Demon can be imagined as a soldier, does this mean that he can follow orders? Perhaps. In his note "Concerning Demons" (c. 1875),

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[57] Thomson, "The Sorting Demon of Maxwell," 126.
[58] Thomson, "Kinetic Theory of the Dissipation of Energy," 442.
[59] William Thomson, "Steps Towards a Kinetic Theory of Matter," *Nature* 30 (1884): 417.
[60] Thomson, "The Sorting Demon of Maxwell," 126.
[61] Maxwell, "Letter to Peter Guthrie Tait. 11 Dec. 1867."
[62] Maxwell, "Notes 'Concerning Demons' and 'Concerning a Molecular Aether.'" Emphasis in original.
[63] Maxwell, *Theory of Heat*, 87.

Maxwell did have a line claiming that Demons were "capable of obeying orders,"[64] but he struck it out. If Maxwell was uncertain whether the Demon of the thought experiment could obey orders, other readers of the thought experiment, asked to think of the Demon as a soldier, might be uncertain about this as well. But perhaps for Maxwell and Kelvin, the possibility of this ambiguity was balanced by the comfort of leaving open the possibility of human escape from the second law, through their personification of the Demon.

IV. Why Soldiers with Cricket Bats?

The specific careers Maxwell and Kelvin use in their descriptions of the Demon may also serve particular functions. Matthew Stanley has already explained why Maxwell may have found the pointsman a particularly apt comparison to present the Demon as a being with free will. [65] In this section, I would like to follow Stanley's lead, and take a closer look at a different career the Demon takes up in Kelvin's descriptions: the soldier with a cricket bat. As I demonstrate in this section, the addition of the cricket bat added even more opportunities for confusion and ambiguity, but also allowed Kelvin to imply that the Demon might be a solution to specific fears associated with entropy: the fears of declining empire and changing culture.

Let me first note the obvious: the image of Maxwell's Demon as a nanoscopic soldier holding a cricket bat is rather silly, in part because it leads to a lot of absurd questions. Does Kelvin envision this "army" as being uniformed? If the Demon is part of an army, does that make the molecules its enemies? Why have they chosen a cricket bat as their cudgel instead of an actual weapon? Moreover, the cricket bat adds even more ambiguity to the thought

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[64] Maxwell, "Notes 'Concerning Demons' and 'Concerning a Molecular Aether.'"
[65] Stanley, "The Pointsman."

experiment. It does not seem to be analogous to any real-world phenomena. The Demon itself is, in Maxwell's original formulation, at least analogous to a valve. The cricket bat is not clearly analogous to anything. The ambiguity only increases if you attempt to interpret the cricket bat within the context of Kelvin's other references to cricket in his scientific writing.

Kelvin's first work on atoms and molecules involved estimating their size.[66] He explains their size using two different comparisons in two different versions of an article entitled "The Size of Atoms."[67] In the version published in *Nature* in 1870, Kelvin estimates that the distance between the centers of contiguous molecules in solids and liquids is between 7.14×10^{-9} and 2.17×10^{-9} centimeters.[68] As a point of comparison, he explains that if a raindrop or a globe of glass the size of a pea were magnified up to the size of the earth, "the magnified structure would be coarser grained than a heap of small shot, but probably less coarse grained than a heap of cricket-balls." In a later version presented before the Royal Institution in 1883, Kelvin provides a larger estimate of 2×10^{-7} to 1×10^{-9} centimeters and explains that if a globe of water or glass "as large as a football" (which Kelvin notes to be 16 centimeters in diameter) were magnified up to the size of the earth, "[t]he magnified structure would be more coarse-grained than a heap of small shot, but probably less coarse-grained than a heap of footballs."[69]

The fact that the change from cricket-balls to footballs accompanies the change in the estimated size demonstrates that at least in some contexts, Kelvin did intend analogies between cricket balls and molecules to have some specificity. However, as physicist Andrew Gray argues,

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[66] Elizabeth Garber, "Kelvin on Atoms and Molecules," in *Kelvin: Life, Labours and Legacy*, ed. Raymond Flood, Mark McCartney, and Andrew Whitaker (Oxford: Oxford University Press, 2008), 194; William Thomson, "Societies and Academies," *Nature* 2 (1870): 56-57.
[67] I learned of the two different version of "The Size of Atoms" from *Kelvin: Life, Labours, and Legacy*, ed. Raymond Flood, Mark McCartney, and Andrew Whitaker (Oxford: Oxford University Press, 2008), 336, n. 13.
[68] William Thomson, "The Size of Atoms," *Nature* 1 (1870): 553.
[69] William Thomson, "The Size of Atoms," *Notices of the Proceedings at the Meetings of the Members of the Royal Institution* 10 (1883): 213.

Kelvin's comparison was "not intended to convey the idea that the molecules are spheres like shot or cricket-balls."[70] Initially, Kelvin thought that it was impossible to determine whether matter was contiguous or composed of discrete molecules, and how these molecules might be modeled.[71] But by 1867, Kelvin had determined the vortex atom to be "the only true atom."[72] In this model, Kelvin posited that atoms were vortices in the luminiferous ether. As historian Elizabeth Garber argues, this opposition to modelling molecules as "elastic-solids" only grew in the 1870s and 1880s.[73] This context confuses how one is to understand Kelvin's addition of the cricket bat. By adding the cricket bat, Kelvin is either asking readers to envision an idea of molecules which he no longer thought was accurate or is asking readers familiar with his thinking on vortices to imagine an absurd image of Demons attempting to bat back swirls in the ether.

The absurdity becomes more pronounced when his unpublished correspondence is considered. There, Kelvin went even further than placing cricket bats in the demons' hands. In 1874, after reading "The Kinetic Theory of the Dissipation of Energy" before the Royal Society of Edinburgh, Kelvin sent a newspaper clipping from the *Edinburgh Courant* reporting on his lecture to Maxwell. On the clipping, Kelvin introduces the idea that these demons might occasionally fail in their mission, further humanizing them. He describes the demons as "never to let himself be beaten far away from his post; rather let molecules pass than that."[74] He also appended another note: "Each demon, himself a club, not over massive, keeps his position in

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[70] Andrew Gray, *Lord Kelvin: An Account of His Scientific Life and Work* (London: J. M. Dent & co., 1908), 262.
[71] Silvanus P. Thompson, *The Life of William Thomson, Baron Kelvin of Largs* (London: Macmillan, 1910), 2:1020.
[72] William Thomson, "On Vortex Atoms," *Proceedings of the Royal Society of Edinburgh* 6 (1867): 1. Kelvin actually suggested a number of molecular models in the last quarter of the nineteenth century, from gyrostatic, rapidly rotating flywheel models to spring loaded molecules embedded in the ether (Garber, "Kelvin on Atoms and Molecules"). For the purposes of this chapter, however, what matters is that none of these models suggests an elastic solid similar to a cricket ball.
[73] Garber, "Kelvin on Atoms and Molecules," 198-99.
[74] James Clerk Maxwell, "Note to Tait 'Concerning Demons,'" in *The Scientific Letters and Papers of James Clerk Maxwell: 1874-1879*, ed. P. M. Harman (Cambridge: Cambridge University Press, 2002), 186. n. 5.

space by watching for and stopping molecules with less energy coming from the other side." It is easy to understand why this metaphor was not included in the speech itself. Here, the Demon becomes a club armed with a cricket bat, an image almost too absurd to imagine.

As in the previous section, I can think of reasons why this ambiguity might have been acceptable to Kelvin. One explanation might be that the cricket bat provided a reliable touchstone for British audiences. New theories in physics, such as the laws of thermodynamics, could become intelligible to most Victorian readers only in a popular conceptual form, and Victorian scientific practitioners considered reframing their ideas into more accessible forms to be an important part of their profession.[75] In "On the Want of Popular Illustrations of the Second Law of Thermodynamics" (1867), Rankine comments on the difficulty Victorians had finding popular explanations of entropy. The addition of the bat can be read as an answer to Rankine's wish for "some means… for making [the second law] as widely understood as the first law of thermodynamics"[76]: the bat may function as an object that was comprehensible for multiple audiences. In Thomas Hughes's *Tom Brown's Schooldays* (1857), Hughes suggests that cricket in particular is a sport which can be understood across classes, as it is "still more or less sociable and universal; there's a place for every man who will come and take his part."[77] Cricket was not quite as democratic as Hughes suggests,[78] but such an object would seem to be a good choice for illustrating a thought experiment for the masses, especially after the boom in interest the sport enjoyed after 1860.[79] But the cricket bat was more than a relatable object; it was also an object

[75] Gillian Beer, *Open Fields: Science in Cultural Encounter* (Oxford: Clarendon Press, 1996), 228.
[76] William John Macquorn Rankine, "On the Want of Popular Illustrations of the Second Law of Thermodynamics," in *Miscellaneous Scientific Papers* (London: Charles Griffin and Company, 1881), 438.
[77] Thomas Hughes, *Tom Brown's Schooldays* (Oxford: Oxford University Press, 2008), 29.
[78] Keith A.P. Sandiford, *Cricket and the Victorians* (Brookfield, Vermont: Ashgate Publishing Company, 1994), 6.
[79] Sandiford, *Cricket and the Victorians*, 162.

that was especially potent in the face of thermodynamic theories that empire might not last forever and that the true nature of the universe was unceasing change and increasing disorder.

As scholars such as N. Katherine Hayles and Thomas Richards have noted, there is a tendency in the writing of Victorian thermodynamicists to discuss physical energy and its conservation or dissipation as if it were a problem of race, nation, or Empire.[80] Different races were described as having different amounts of energy. For example, Charles Lyell's *Travels in North America* (1845) creates a racial hierarchy by arguing that "it would be visionary to expect that… [negroes] could at once acquire as much energy, and become as rapidly progressive, as the Anglo-Saxons."[81] It would have been comforting, therefore, to feel that this energy was not subject to the second law. For example, in Balfour Stewart and J. Norman Lockyer's "The Place of Life in a Universe of Energy" (1868), they note that "There is, in fact, a tendency abroad to change all kinds of energy into low-temperature heat equally spread about,--a thing that is of no possible use to anyone."[82] On the one hand, this use of "abroad" serves as a reminder that the thermodynamics they are describing applies to the entire universe. On the other, the implication is that such a tendency is not the case at home. Stewart and Lockyer are certainly not suggesting that the laws of thermodynamics do not apply within the borders of Victorian Britain. But they are clearly interested in imagining a Britain which has fine enough control over its use of energy that it might avoid this kind of dissipation. Elsewhere in the article, they explain how small expenditures of energy, such as starting an electric current, can trigger large amounts of mechanical action, such as exploding a magazine overseas. They point out that such careful

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[80] Richards, *Imperial Archive*, 87; N. Katherine Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (Ithica: Cornell University Press, 1990), 41.
[81] Charles Lyell, *Travels in North America, in the Years 1841-2; with Geological Observations on the United States, Canada, and Nova Scotia* (New York: Wiley and Putnam, 1845), 152.
[82] Stewart and Lockyer, "Sun as a Type of the Material Universe," 322-3.

direction of energy might "even win an empire."[83] This connection of energy concerns to empire makes a certain etymological sense, as Barri Gold notes that the earliest English uses of dissipation "refer to political contexts: 'sub[v]ersions of empires and kingdoms, scatterings and dissipacions [*sic*] of nations.'"[84]

These imperial concerns make the soldier holding a cricket bat an appropriate figure for a fiction of escape from entropy. Sandiford argues that cricket was seen as a sport which solely belonged to the British (or sometimes more narrowly the English): "they glorified it as a perfect system of ethics and morals which embodied all that was most noble in the Anglo-Saxon character. They prized it as a national symbol, perhaps because – so far as they could tell – it was an exclusively English creation unsullied by oriental or European influences."[85] Numerous examples could be listed of this assertion throughout the nineteenth century, but the most famous is probably Thomas Hughes's assertion in *Tom Brown's Schooldays* that cricket was "an institution… the birthright of British boys old and young, as habeas corpus and trial by jury are of British men."[86]

It was always boys and men. Like many other toys for children, the cricket bat was an object associated with a particular gender. For example, in Mary Ann Kilner's *Memoirs of a Peg-Top* (c. 1800), a novel of circulation aimed at young children, one young boy mocks his sister with a poem in which he confidently asserts the following:

> I ne'er yet saw a lady at cricket engage,
> Although you just now flounc'd away in a rage;
> When you took up my bat with so awkward an air,
> And I told you such toys were not made for the fair[.][87]

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[83] Stewart and Lockyer, "Sun as a Type of the Material Universe," 324-25.
[84] Gold, *ThermoPoetics*, 143.
[85] Sandiford, *Cricket and the Victorians*, 1.
[86] Hughes, *Tom Brown's Schooldays*.
[87] Mary Ann Kilner, *Memoirs of a Peg-Top* (York: T. Wilson and R. Spence, c1800), 70.

Kilner does make clear to her audience that she disagrees with this assessment. But the connection between cricket and masculinity continued throughout the century. In *The Pickwick Papers*, for instance, the ladies remain behind while the men go to observe the grand match between All-Muggleton and Dingley Dell.[88]

The cricket bat therefore reinforces the already masculine gendering of Maxwell's Demon.[89] One of the ways in which Victorian thermodynamicists conceptualized the supposed dissipation of energy was as a weakening of masculine ideals. In *The Unseen Universe* (1875), Balfour Stewart and Peter Guthrie Tait express their belief that dissipation of entropy was tied to dissipation of morality by lamenting that the days when "men fought with men" with "irrepressible energy" seemed to have passed.[90] The masculine cricket ground served as a place for the form of masculine competition that Tait and Stewart feared had been lost to be reasserted.

The link between cricket and British masculinity was furthered by the link between cricket and British soldiers. Like many sports, cricket matches were often described as battles. For example, in Trollope's *The Fixed Period* (1882), Trollope's dystopian novel about the fictional, twentieth-century country of Britannula, the narrator reflects on how the cricket match between Britain and Britannula, "which should have been regarded as no more than an amusement,--as a pastime" is regarded "as though a great national combat had been fought."[91] Cricket was also associated with British soldiers because in 1841, the Duke of Wellington ordered that each military barracks was to be accompanied by a cricket ground.[92]

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[88] Charles Dickens, *The Pickwick Papers* (Philadelphia: T. B. Peterson, c1850), 111-15.
[89] Thomson, "Kinetic Theory of the Dissipation of Energy," 442; Thomson, "The Sorting Demon of Maxwell," 126.
[90] Balfour Stewart and Peter Guthrie Tait, *The Unseen Universe; or, Physical Speculations on a Future State* (London: Macmillan and Co., 1875), 107. Emphasis in original.
[91] Anthony Trollope, *The Fixed Period: A Novel* (Edinburgh: Blackwood, 1882), 1:167.
[92] Sandiford, *Cricket and the Victorians*, 161.

The connection between cricket bats and forms of conventional Victorian masculinity meant that it could serve as a much-desired symbol of tradition. In his famous essay on "The Scientific Use of the Imagination" (1870), John Tyndall invokes the challenges of the new theories of entropy and evolution by prefacing it with an epigraph from Emerson:

> The rushing metamorphosis
> Dissolving all that fixture is,
> Melts things that be to things that seem,
> And solid nature to a dream.[93]

Many Victorians worried about where this metamorphosis might lead. Bad enough that modern life came with a set of troubling political movements and dizzying technological innovations. But what was it all for, if every piece of coal brought humanity closer to the end?

As Keith Sandiford has argued, cricket often served as a symbol of the past and custom for the Victorians. The game was modernized during the Hanover period and had more or less taken on its modern form by 1840: "The Victorians could, as a consequence, treat cricket with the same awe and reverence that they reserved for ancient and durable institutions. They lived in a revolutionary world of constant flux… The great technological changes by which they were enveloped left them with both a sense of pride and a feeling of insecurity… Hence their devotion to Crown and cricket."[94] In truth, it was the trains and work week that came with modern industry that spurred the cricket boom after 1860.[95] But as a symbol, cricket summoned the image of a Victorian Britain without the costs of modernity. We can, therefore, interpret Kelvin's decision to present the Demon, absurdly, as a soldier with a cricket bat as an answer to fears of

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[93] John Tyndall, "On the Scientific Use of the Imagination. A Discourse. Delivered before the British Association at Liverpool September 16, 1870," in *Fragments of Science for Unscientific People; a Series of Detached Essays, Lectures, and Reviews* (New York: D. Appleton, 1872). This epigraph appears in *Fragments of Science* but not in other versions of this essay.
[94] Sandiford, *Cricket and the Victorians*, 1.
[95] Sandiford, *Cricket and the Victorians*, 54.

weakening imperial power, the dissipation of masculine energy, and the mutability of modern life.

V. "Obstructing the Field" to Encourage Replay

As I analyzed the absurd details of Maxwell and Kelvin's descriptions of the Maxwell's Demon thought experiment, I slowly came to realize that an important benefit of this absurdity was that it encouraged readers to think about these details: to try to work out why they were included and whether they matter. To use an analogy from the Laws of Cricket, one might even say that Maxwell and Kelvin are "obstructing the field": "willfully attempt[ing] to obstruct or distract… by word or action."[96] Details like Kelvin's offhand decision to include a cricket bat in the thought experiment seem to beg readers to try to make sense of them. And, in trying to make sense of these details, readers may find themselves reconsidering this thought experiment multiple times, as I did. The inclusion of absurd details in thought experiments encourages readers to reconsider and re-run these mental experiments many times. In fact, more thought experiments may benefit from the inclusion of seemingly arbitrary or absurd details for exactly this reason.

Defining what constitutes a "thought experiment" is a notoriously difficult task. As James R. Brown writes in *The Laboratory of the Mind* (1991), "Thought experiments are performed in the laboratory of the mind. Beyond that metaphor it's hard to say what they are."[97] This broad definition is generally echoed by other scholars such as Edward A. Davenport, Peter Swirski, and

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[96] Marylebone Cricket Club, "Law 37. Obstructing the Field," MCC Foundation, www.lords.org/mcc/laws/obstructing-the-field.
[97] James R Brown, *The Laboratory of the Mind: Thought Experiments in Natural Sciences* (New York: Routledge, 1991), 1.

Yiftach Fehige.[98] Attempts to provide stricter definitions often end up excluding commonly recognized thought experiments.[99] Moreover, scholars often disagree over how (or if) thought experiments produce new knowledge.[100]

What cannot be denied is that thought experiments are famous for their brevity; many scholarly descriptions of thought experiments describe them as only including the details needed to perform their experiment. In fact, some scholars, such as John Norton, argue that the details of the thought experiment are epistemologically irrelevant. Thought experiments for Norton are merely "arguments disguised for rhetorical reasons"[101] and he claims that he can reconstruct any thought experiment into an argument based on tacit or explicit assumptions. In contrast, Nathan Crick has argued that the rhetorical aspects of thought experiments are essential to the production of knowledge, as the appeal to the creative imagination of the reader allows cooperation between the scientific practitioner or philosopher and the audience.[102] As Brown and Fehige claim in an encyclopedia article on "Thought Experiments," "the more detailed the imaginary scenario in the relevant aspects, the better the thought experiment."[103] The audience for the thought experiment—which often includes both experts and nonexperts—needs enough detail to be able to properly run the experiment in their mind. But what are the relevant aspects of the thought experiment? Brown and Fehige admit that there is not a clear way of knowing and suggest that there may not even be a solution to this problem.

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[98] Edward A Davenport, "Literature as Thought Experiment (on Aiding and Abetting the Muse)," *Philosophy and the Social Sciences* 13 (1983): 281; Peter Swirski, *Of Literature and Knowledge: Explorations in narrative Thought Experiments, Evolution, and Game Theory* (New York: Routledge, 2007), 97; James R Brown and Yiftach Fehige, "Thought Experiments," https://plato.stanford.edu/entries/thought-experiment.

[99] Swirski, *Of Literature and Knowledge*.

[100] David Davies, "Thought Experiments and Fictional Narratives," *Croatian Journal of Philosophy* 29 (2007).

[101] John D Norton, "Are Thought Experiments Just What You Thought?," *Canadian Journal of Philosophy* 26, no. 3 (1996): 339.

[102] Nathan Crick, "Conquering Our Imagination: Thought Experiments and Enthymemes in Scientific Argument," *Philosophy and Rhetoric* 37, no. 1 (2004).

[103] Brown and Fehige, "Thought Experiments."

My experience trying to explain some of the absurd details in the Maxwell's Demon thought experiment suggests that 'irrelevant' aspects of thought experiments may still be valuable. There is, as I noted, no reason why Maxwell's Demon should need to be personified: having a human form makes absolutely no difference in how the Demon actually functions. It certainly is not necessary to imagine the Demon holding a cricket bat. But there is something enthralling about the irrelevant or incongruous elements of thought experiments. In a genre of scientific writing defined by brevity, finding an element that is not necessary is like being given a puzzle with an extra piece. When you've completed the puzzle, you cannot help but look back at it again, to see if there is somehow a way of making that piece fit.

Maxwell's Demon is not the only thought experiment that includes superfluous details that encourage readers to reconsider the thought experiment multiple times. Why does Schrodinger's cat have to be a cat? It does not, of course, but readers who pause to consider this question will spend more time considering this thought experiment. Nor is this limited to thought experiments in the physical sciences. One might similarly ask why Judith Jarvis Thomson's famous thought experiment about abortion compares a fetus to an unconscious violinist. Rather than removing details from thought experiments, as Norton would suggest, perhaps thought experiments might be more valuable if more included absurd details that encouraged readers to engage with them, even if those details do add some ambiguities.

VI. Conclusion

An army of microscopic men with cricket bats sounds like an absurd fever dream, rather than the basis for a thought experiment which to this day is used to speak to the limitations of the second law of thermodynamics. And yet, as discussed, Kelvin's imaginative play in this thought experiment likely provided a reference point for readers conducting the thought experiment as well as helping to assuage anxieties they might have had about the second law by constructing a specifically British and masculine fiction of escape.

In this chapter, I have only focused on Maxwell and Kelvin's formulations of this thought experiment. The late-nineteenth and early-twentieth centuries would see the Demon increasingly brought to bear as a figure for understanding other scientific phenomena In 1879, the anonymous author of "Some Points in the History of Spectrum Analysis" imagined a Demon which could sort out the different components of molecules.[104] In his 1886 opening address to the Chemical Section of the British Association, William Crookes describes certain separation processes (fractionation) as acting "the part of a chemical 'sorting Demon,' distributing the atoms of yttrium into several groups."[105] In 1896, an anonymous article on "Individuality in the Mineral Kingdom" used the figure of the Demon to demonstrate the regularity of molecular arrangements in crystallography.[106] In 1905, A. Irving wondered whether the function of nitrogen in chlorophyll might be similar to "the magic 'demon' (borrowing a figurative from Clerk Maxwell) that holds the wand."[107] Most famously, in 1929, Leo Szilard complicated the Maxwell's Demon thought experiment by connecting it to information theory.[108] As Bruce Clarke says in *Energy Forms: Allegory and Science in the Era of Classical Thermodynamics* (2001), this flexibility is evidence that "the crucial thing [about Demons] is that they can take whatever shape the larger conceptual scheme demands: they are inherently metamorphic."[109]

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[104] Some Points in the History of Spectrum Analysis," *Nature* 21 (1879).
[105] "The British Association," *Nature* 34 (1886): 409.
[106] "Individuality in the Mineral Kingdom," *Nature* 54 (1896).
[107] A. Irving, "The Romance of the Nitrogen Atom," *Nature* 72 (1905).
[108] Leo Szilard, "NASA TT F-16723. On Entropy Reduction in a Thermodynamic System by Interference by Intelligent Subjects," (NASA, 1976).
[109] Bruce Clarke, *Energy Forms: Allegory and Science in the Era of Classical Thermodynamics* (Ann Arbor: University of Michigan Press, 2001), 85.

As the thought experiment spread into new contexts, the exact details of the original formulations seemed to matter less. The personification of the Demon – especially comparisons of the Demon to a soldier, pointsman, or other profession – was referenced less frequently. As the thought experiment was popularized, scientific practitioners began to treat it, not as an experiment to consider, but rather as a fait accompli. For example, at the end of the century, at a meeting of the British Association, physicist J. H. Poynting expressed his fear that physicists might be too often treating hypotheses about the ether and molecules as fact. One of his illustrations of this refers to the Second Law: "I suspect that it is sometimes supposed… that the mere imagining of a Maxwell's sorting demon has already disproved the universality of the law; whereas he is a mere hypothesis grafted on a hypothesis, and nothing corresponding to his action has yet been found."[110]

Absurd as it may be, Kelvin's image of a microscopic army holding cricket bats has this benefit: no one is likely to assume that something corresponding to this has been found in nature. The absurdity of Kelvin's fantasy helps to forestall the possibility of taking molecular hypotheses for granted by drawing attention to thought experiments' artificiality and fictionality. Moreover, the absurdity of this image provides consideration of the second law some much needed levity. Among the many fictions of escape from heat death and entropy in the Victorian period, Maxwell's Demon is unique. Rankine's idea of a universal boundary that might eventually re-concentrate energy may have provided some with hope, but Maxwell's Demon was the only figure of fun. This, more than anything else, should be the legacy of Maxwell's Demon. Maxwell hinted as much in his first letter to Tait about the thought experiment, in which he described it, in his characteristically droll way, as proof that "energy need not always be dizzy

[110] "The Dover Meeting of the British Association," *Nature* 60 (1899): 473.

pated [dissipated] in the present wasteful world."[111] It is this type of weak wordplay that ultimately characterizes the Demon. The Demon is an absurd figure, but it is this absurdity that makes the figure worth revisiting. It is fun to imagine an army of Demons, even if it is hard to reconcile the various elements. The Demon personified, with a cricket bat in his hands, or sitting at a pianoforte, or momentarily transforming himself into a cricket bat, is like a joke which does not quite make sense. It is the kind of joke one might tell when facing the idea of the cooling of the earth, the death of the sun, the end of the universe.

[111] Maxwell, "Letter to William Thomson. 16 January 1868."

Chapter 5 – Diversion or Development? Play and the Scientific Life in Charles Darwin's *Recollections*

I. Introduction

Writing in 1876 about his ambition to "take a fair place among scientific men," Charles Darwin makes clear that one of the required characteristics of scientific practitioners was their ability to work.[1] In his autobiography, *Recollections of the Development of my Mind and Character*, he repeatedly turns to work as a way of defining himself, claiming that his "chief enjoyment and sole employment throughout life has been scientific work";[2] that his "industry has been nearly as great as it could have been in the observation and collection of facts";[3] and that he has "worked as hard and as well as [he] could, and no man can do more than this."[4] As we saw in Chapter One, Darwin was not alone, in the genre of scientific life writing, in connecting his science to the idea of work. This was, to paraphrase Paul White, a specifically Victorian way of thinking about science.[5]

If, in Darwin's life writing, recollections and assertions of his work provided his membership in the scientific community, what use does he make of his recollections of his play? Linda Peterson's *Victorian Autobiography* (1986) interprets the appearance of details such as

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[1] Charles Darwin, *The Autobiography of Charles Darwin*, ed. Nora Barlow (London: Collins, 1958), 81. After Francis Darwin's publication, Darwin's granddaughter Nora Barlow later restored several omitted passages for her 1958 edition, retitled *The Autobiography of Charles Darwin*. Whenever this article makes references to *Recollections* or Darwin's autobiography, it is referring to Barlow's reprinted version of *Recollections of the Development of my Mind and Character*, unless the author's fair copy manuscript held at Cambridge is specified.
[2] C. Darwin, *The Autobiography of Charles Darwin*, 115.
[3] C. Darwin, *The Autobiography of Charles Darwin*, 141.
[4] C. Darwin, *The Autobiography of Charles Darwin*, 126.
[5] Paul White, *Thomas Huxley: Making the 'Man of Science'* (Cambridge: Cambridge University Press, 2003), 60.

Darwin's love of angling and hunting in the early parts of *Recollections* as a way of modelling his own Baconian scientific method within the autobiography. According to Peterson, Darwin includes details of his early recreations as part of his "undirected gathering of facts," without any "concern for literary coherence," which will later allow Darwin to arrive at a comprehensive theory about himself from this random data.[6] I do not want to contest the fact that Baconian ideals are structuring Darwin's autobiography; however, Darwin's recollections of his recreations as a child and young adult are not random or without literary coherence. I argue that in Darwin's autobiography, his youthful recreations, such as catching beetles and hunting, act as foreshadowing of later scientific interest or as diversions which must be overcome, before he becomes a 'man of science' in the second half of his narrative. Darwin's autobiography demonstrates Darwin's belief that play is essential to the development of scientific workers like himself and provides a model for readers to follow.

II. Darwin from a Distance: Context for Darwin's Scientific Life

Ostensibly written for his "children and grandchildren," *Recollections* (written in 1876, originally published as part of his son Francis Darwin's *Life and Letters of Charles Darwin* (1887)) essentially proceeds chronologically, from Darwin's earliest memories to his most recent biological work.[7] It is not until the midpoint of his narrative that Darwin makes his first strong claim that his life should be understood as one of 'work.' On the 60th of 121 manuscript pages, Darwin asserts that after he opened his first notebook related to the *Origin of Species* in 1837, he "never ceased working on for the next twenty years."[8] The manuscript reveals that this was

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[6] Linda H. Peterson, *Victorian Autobiography: The Tradition of Self-Interpretation* (New Haven, CT: Yale University Press, 1986), 159.
[7] C. Darwin, *The Autobiography of Charles Darwin*, 21.
[8] C. Darwin, *The Autobiography of Charles Darwin*, 83.

initially a much narrower claim, in which Darwin asserted that after opening the notebook he had "never ceased working on *this subject* for the next twenty years."[9] The change emphasizes that this was the beginning of Darwin's life as a worker more generally, suggesting that such persistent work likely bled into all facets of his life.

Darwin structured *Recollections* around his development into what Lorraine Daston and Peter Galison claim was the ideal of Victorian science, the "indefatigable worker."[10] There is a clear shift from play- to work-related terms after Darwin describes the beginning of his work on *The Origin of Species* in the text. As Figure 5-1 demonstrates, many of the terms associated with playfulness, such as *play*, *sport*, and *pleasure* are more prevalent in the first half of the narrative than the second. In contrast, the terms *work* and *labor* are more prevalent in the second half. There are some outliers: for example, references to "amusement" actually increase. But from a distance, it certainly appears that Darwin views the path to becoming a successful scientific practitioner as one in which his early play is replaced by or transitions into opportunities for hard work.

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[9] Charles Darwin, "Recollections of the Development of My Mind and Character (Author's Fair Copy)," DAR26, Charles Darwin Papers, Cambridge University Library, Cambridge, U.K, 60.

[10] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010), 44. In saying this, I certainly do not want to suggest that the play/work binary is the only theme structuring *Recollections*. As works such as Linda Peterson's *Victorian Autobiography* and Alexis Harley's *Autobiologies: Autobiologies: Charles Darwin and the Natural History of the Self* (Lewisburg, Bucknell University Press, 2015) have discussed, there are several issues shaping the form of Darwin's autobiography, including Darwin's attempt to frame his life within an evolutionary framework, his desire to model his interpretation of himself on his own Baconian scientific methodology, and familiar literary tropes of figures travelling abroad and then returning home.

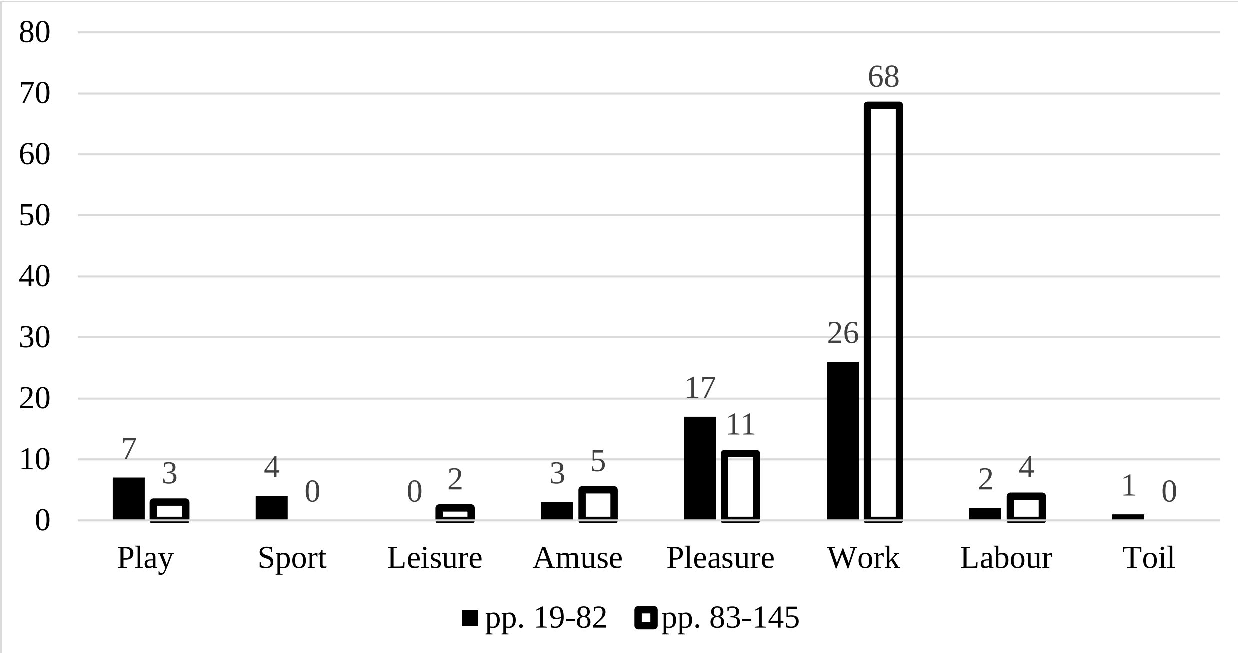

Figure 5-1: Frequency of terms associated with Work and Play in Darwin's *Recollections*

Today, extensive discussions of childhood and early adult recreations as a prelude to a later work identity is a common strategy in scientific life writing. Richard Feynman, for instance, has used it to great effect in his reflections on his life.[11] One can find some examples of this logic within nineteenth-century science texts. As I discussed in Chapter Two, this is a logic that was used to justify rational recreation for children, as in John Ayrton Paris's *Philosophy in Sport*. The year before Darwin began writing his *Recollections*, this logic also appeared in the *Life of Sir Roderick I. Murchison* (1875). Murchison, "tired of all fox-hunting life" is encouraged by Sir Humphry Davy to "*set to* at science" instead.[12] As David Amigoni points out, Darwin's autobiography was published in the midst of a resurgence of interest in scientific life writing

[11] Richard Feynman, *"Surely You're Joking, Mr. Feynman": Adventures of a Curious Character* (New York: Norton, 1997).
[12] Archibald Geikie, *Life of Sir Roderick I. Murchison, Bart.,; K. C. B., F. R. S.; Sometime Director-General of the Geological Survey of the United Kingdom* (London: J. Murray, 1875), 1:94.

thanks to figures like Grant Allen.[13] However, the genre of scientific life writing was still being developed, and extended discussions of such recreations in scientific life writing was rare.

Scientific life writing needed to serve several functions. Biographies and autobiographies of scientific practitioners served as capstones to their work, especially in the case of posthumously published "Life and Letters" volumes, which often reintroduced older scientific articles and essays to the public.[14] They also helped to advocate and maintain science's cultural authority in Britain.[15] But perhaps their most important responsibility was providing a model for other practitioners (or for any interested readers). As Steven Shapin has argued, life writing about scientists frequently served as a space for thinking about what aspects of a scientist's life were relevant to their scientific identity.[16] For instance, one reviewer, praising Darwin after his autobiography was published in 1887, emphasized that Darwin "was at much pains to put on record his own habits and modes of thought, if they were at all likely to be of service to those who should follow him in the pursuit of truth."[17] These texts describe the scientific practitioner: how do they act, in their work spaces and in their private lives? Do they approach their research with passion, or do they create knowledge through drudgery? Are they defined by their scientific discoveries, or is their science overshadowed by their role as a gentleman, or a politician, or a parent? But these texts also explain how the subject claimed the identity of 'man or woman of

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[13] David Amigoni, "Writing the Scientist: Biography and Autobiography," in *The Routledge Research Companion to Nineteenth-Century British Literature and Science*, ed. John Holmes and Sharon Ruston (Abingdon, Routledge, 2017), 136.
[14] It should also be noted that in summarizing scientific works, scientific life writing could often stir up new scientific controversies. For instance, John Tyndall complained in a letter to Rudolf Clausius that Peter Guthrie Tait was using the *Life and Letters of James David Forbes* (1873) to attack Tyndall and Clausius (John Tyndall, "Letter to Rudolf Clausius. 27 June 1873," 1873, JT/1/T/205, The Papers of John Tyndall, The Royal Institution Archives, London.
[15] Amigoni, "Writing the Scientist: Biography and Autobiography," 13. For examples of other groups that also used life writing in this way, see Atkinson, *Victorian Biography Reconsidered*, 7.
[16] Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008), 8, 53.
[17] H. H. Higgins, "On the Life and Letters of Charles Darwin," *The Open Court, a Quarterly Magazine* 57.2 (27 Sep. 1888): 1231.

science,' 'scientific worker,' 'natural philosopher,' or, later in the century, 'scientist.' Were these practitioners born with the taste for science, or did it develop later in life? Did the practitioner have a family connection to the sciences, or did they work their way into the scientific community? Borrowing a term which Steven Shapin has applied to twentieth-century scientists, I label this narrative of how to develop into a scientific practitioner the "scientific life."[18]

Modelling how one develops into a scientific practitioner was not easy when the 'scientific worker' was not yet a firmly established profession. Until the early Victorian period scientific practitioners were often clergymen by vocation, or—like Darwin—had enough inherited wealth to pursue their science regardless of financial remuneration. As Shapin points out, even when acting as a geologist on the *Beagle* expedition to South America, during which he began to develop his theory of evolution, Darwin was not employed: his father actually paid £1200 for Darwin to accompany Robert Fitzroy as a guest. Describing scientific practice through work rhetoric allowed scientific life writing to emphasize that these activities were pursued as a career rather than as a hobby, and so one finds subjects 'work' is more often a focus of these texts then their 'play.' Occasionally scientific (auto)biographers even excise accounts of their subjects' play, claiming it is not generally interesting or is irrelevant.[19]

By the time Darwin began writing *Recollections*, scientific life writing was also beginning to move beyond the hagiographies common earlier in the century to a focus on what Steven Shapin calls "honest biographies," which demonstrate an increasing interest in biographical elements outside what was typically presented to the public. These biographies were not immune to the censorship common in the Victorian period. (Virginia Woolf quipped

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[18] Shapin, *The Scientific Life*, 2.

[19] See, for instance, John Ayrton Paris, *The Life of Sir Humphry Davy* (London: H. Colburn and R. Bentley, 1831), 1: 7-8; Joseph Huddart the Younger. *Memoir of the Captain Joseph Huddart, F.R.S., &c*. (London: W. Phillips, 1821), 52.

that "Victorian biographies are like the wax figures now preserved in Westminster Abbey […] effigies that have only a smooth superficial likeness to the body in the coffin").[20] But it was hoped that these biographies could include details about the subject's life—possibly even embarrassing details—without devaluing their science. As British mathematician Augustus de Morgan wrote about biographies of Isaac Newton: "Let a flaw be a flaw, because it is a flaw. Newton is not the less Newton."[21]

This magnanimity was only aspirational. In practice, scientific practitioners often have their credibility wounded by their flaws, especially if they have the misfortune to reveal these flaws while they are still alive. It is therefore surprising how little hesitation Darwin shows in including possibly irrelevant details about "his love of angling and hunting" and other recreations. This is especially true because, despite Darwin's claim that he had "taken no pains about [his] style of writing" in *Recollections*, his manuscript also reveals several revisions, many of which suggest that Darwin was aware that this work might eventually be shared with a larger audience, which might judge his actions.[22] For instance, in one early account, Darwin reveals how he used to sneak into the kitchen as a boy to steal fruit. While Darwin was willing to admit this minor crime, he was apparently unwilling to appear as a habitual thief, and so his manuscript revises "I often stole fruit" to "I sometimes stole fruit."[23] As I shall show below, Darwin does consider some of his recreations to be flaws that might be judged negatively, and yet he seems to cheerfully dedicate much of the first half of his narrative to these activities.

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[20] Virginia Woolf, "The New Biography" (1927), qtd. in Atkinson, *Victorian Biography Reconsidered*, 1.
[21] Augustus de Morgan, *Essays on the Life and Work of Newton*, ed. Philip E. B. Jourdain (Chicago: Open Court Publishing, 1914), 182.
[22] C. Darwin, *The Autobiography of Charles Darwin*, 21.
[23] C. Darwin, "Recollections of the Development of My Mind and Character (Author's Fair Copy)," 2.

As Sidonie Smith and Julia Watson argue in *Reading Autobiography* (2001), "imaginative acts of remembering always intersect with such rhetorical acts as assertion, justification, judgement, conviction, and interrogation."[24] Remembered acts of play in scientific life writing are therefore always justified by the text, even if the narratorial voice of the scientific practitioner or biographer does not articulate an explicit justification. Rather than being randomly incorporated, these recollections were carefully chosen for inclusion in the autobiography. Indeed, several of the early recreations—for instance, his fondness for collecting eggs and his "strong taste for angling—were inserted as appendices to the original manuscript.[25] It is therefore clear that Darwin did think that play was an important part of development in the scientific life.

III. Prescientific Recreations

Before writing *Recollections*, Darwin had already begun to reflect on his childhood recreations in his earliest autobiographical fragment, "Life" (1838). In that fragment, Darwin tells stories of his fishing for newts, gardening, and collecting seals, franks, and pebbles, emphasizing the "pleasure" and "delight" the activities brought him.[26] In "Life," these recreations are presented as an early form of the biological and geological work he would pursue in later life. For instance, one account describes the pleasure he felt telling stories about animals he claimed to have witnessed: "I scarcely ever went out walking without saying I had seen […] a pheasant or some strange bird, (natural History taste). These lies, when not detected, I presume excited my attention, as I recollect them vividly,. [*sic*] -- not connected with shame, though some I do, but as

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[24] Sidonie Smith and Julia Watson, *Reading Autobiography* (Mineapolis, MN: University of Minnesota Press, 2001), 6.
[25] C. Darwin, "Recollections of the Development of My Mind and Character (Author's Fair Copy)," 4.
[26] Charles Darwin, "'Life. Written August – 1838' [An autobiographical fragment]," *The Complete Works of Charles Darwin Online*, ed. John van Wyhe (2 July 2012), 4-5.

something which by having produced great effect on my mind, gave pleasure, like a tragedy."[27] Darwin describes this imaginative play as being undertaken for excitement and pleasure, but also parenthetically notes that this is related to "natural History taste." Although unexplained within the fragment, this is clearly meant to be interpreted as part of a claim that he makes in the following pages and would later reiterate in *Recollections*: that he was "born a naturalist."[28] From his earliest biographical writing, therefore, Darwin was interested in seeking out ways in which he could use his childhood recreations to foreshadow or explain his later scientific work. I call these accounts, in which Darwin justifies his recreations by framing them as the first step in his scientific work, what I call *prescientific recreations*. They are not scientific practice yet, but the reader is clearly meant to understand that they are part of the development of a scientific practitioner.

Forty years later, when writing *Recollections*, Darwin would return to the same types of recreations, using the same justification for their inclusion within that text. Again, he mentions gardening and collecting, adding new recreations such as his chemical experiments with his brother.[29] Again he emphasizes that these were activities primarily undertaken for the "zeal," "pleasure," "satisfaction," "delight," "interest," and "passion" they inspired.[30] As prescientific recreations, such play is acceptable, even unavoidable, as a form of training. Take, for instance, a story which Darwin shares in the autobiography as "proof of [his] zeal": "one day… I saw two rare beetles and seized one in each hand; then I saw a third and new kind, which I could not bear to lose, so that I popped the one which I held in my right hand into my mouth. Alas it ejected

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[27] C. Darwin, "Life. Written August – 1838," 4.
[28] C. Darwin, "Life. Written August – 1838," 4-5.
[29] C. Darwin, *The Autobiography of Charles Darwin*, 23-24, 26-27, 43, 45.
[30] C. Darwin, *The Autobiography of Charles Darwin*, 43, 45, 62.

some intensely acrid fluid, which burnt my tongue so that I was forced to spit the beetle out, which was lost..."[31] While this is an amusing story, it also suggests that Darwin's passion for biological subjects was not always the result of rational choices. It appears as a more innate drive.

Even behavior which would be undeniably immoral in other contexts could, when framed as a prescientific recreation, be excused. Relating how he would, as a child, "invent[] deliberate falsehoods… for the sake of causing excitement," Darwin describes how he told another boy that he "could produce variously coloured Polyanthuses and Primroses by watering them with certain coloured fluids, which was of course a monstrous fable."[32] While Darwin hopes that the fact that he still remembers this event is proof of his "conscience having been afterwards sorely troubled by it," there is little evidence that this is the case. Perhaps the reason he is uncertain of whether he truly regrets the event is because it is also evidence that he "was interested at this early age in the variability of plants." Even the vehemently anti-evolution review of *The Life and Letters of Charles Darwin* in *The Dublin Review* could not bring itself to criticize Darwin for these actions. The review emphasizes that these claims, Darwin's first "scientific facts" are really "fictions," evidence of "childish untruthfulness.[33] But rather than using these accounts as evidence that the adult Darwin may have been equally mendacious, they instead suggest that these early lies may have led Darwin to become "truth-loving," full of dread at the idea that he might "misrepresent another, or himself be misunderstood."

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[31] C. Darwin, *The Autobiography of Charles Darwin*, 62.
[32] C. Darwin, *The Autobiography of Charles Darwin*, 23.
[33] "Art. VII.--Darwin's Life and Letters," *Dublin Review* (April 1888), in DAR 134.7, Apr. 1888, Charles Darwin Papers, Cambridge University Library, University of Cambridge, Cambridge, U.K.

Recreations which foreshadow his later scientific work therefore seem vulnerable to only the mildest reprobation. Moreover, in presenting this as an inherited trait, rather than a conscious choice, Darwin shields himself from some level of personal responsibility. The text implies that his interest in these recreations was really the fault of ancestors like Erasmus Darwin, who, Darwin reveals in a separate biography, also had a passion for prescientific recreations at a young age.[34] Prescientific recreations, as presented by Darwin, occasionally led him into immoral behavior, but certainly were not inimical to his scientific identity.

IV. Unscientific Diversions

In contrast to unoffending prescientific recreations, there is a second category of recreational activities within *Recollections* which are presented as being useless and morally suspect and are explicitly contrasted to both his prescientific recreations and his later scientific work. Darwin uses what I call *unscientific diversions* to represent himself as a dissolute, somewhat idle youth, too apt to choose play and amusement over hard work.[35] Unlike pre-scientific recreations, these diversions are presented as an obstacle to or deviation from his scientific development. For instance, he recalls, with deep mortification, his father's warning that "You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family," and admits that his "probable destination" was that he would turn into "an idle sporting man."[36] He describes his passion for sporting as if it bordered on idolatry, putting his love of shooting birds at the same level as others' "zeal for the most holy cause."[37] These unscientific diversions even overpower Darwin's innate taste for science. The only time he describes himself as having "no

[34] Ernst Krause, *Erasmus Darwin* (London: J. Murray, 1879), 6.
[35] C. Darwin, *The Autobiography of Charles Darwin*, 21.
[36] C. Darwin, *The Autobiography of Charles Darwin*, 28, 56.
[37] C. Darwin, *The Autobiography of Charles Darwin*, 44.

great zeal" for collecting shells (a prescientific recreation) comes shortly before a summer vacation "wholly given up to amusements" and "devoted to shooting," and he emphasizes that in those days, he "should have thought [himself] mad to give up the first days of partridge-shooting for geology or any other science."[38]

His Cambridge years are described as particularly bacchanalian: "my time was sadly wasted there and worse than wasted. From my passion for shooting and for hunting and when this failed, for riding across country I got into a sporting set, including some dissipated low-minded young men. […] we sometimes drank too much, with jolly singing and playing at cards afterwards."[39] Did Darwin really have such a proclivity to dissolute play? It would explain the coat of arms designed for Darwin by his friend at Cambridge, Albert Way. Historian John van Wyhe notes that Way's design included "crossed tobacco pipes, meerschaum pipes, cigars, a wine barrel and beer tankards" that imply that "drinking and smoking were Darwin's trademarks."[40] Darwin's description of Cambridge as "time sadly wasted" also echoes William Makepeace Thackeray's humorous critiques of the declining values of university students in his *Etchings of university student life in 1829*.[41] In those etchings, Thackeray depicts Cambridge life as one that had a dissipating effect on undergraduates. When the student of Thackeray's etchings arrives at the university, he devotes himself to "Worldly Study," but later finds himself distracted and imposed upon by the "dissipated low-minded young men" Darwin cites. In the first term, the student is solitary and studious, but by the second term the student has become a debauched playboy, drinking and smoking, with lascivious nudes on the walls, as well as, interestingly, a

[38] C. Darwin, *The Autobiography of Charles Darwin*, 53-4, 71.
[39] C. Darwin, *The Autobiography of Charles Darwin*, 60.
[40] John van Wyhe, *Charles Darwin in Cambridge: The Most Joyful Years* (Hackensack, N.J.: World Scientific Publishing Co., 2014), 33.
[41] For more, see van Wyhe, *Charles Darwin in Cambridge*, 50.

net, which could have been of use either for the idle fisherman or, in the case of Darwin, the amateur collector of beetles. But while this may indeed have been the culture of young men at Cambridge, Francis Darwin, who perhaps has reason to attempt to walk back his father's confession of playfulness, includes an editorial footnote after his father's account asserting that his father has "exaggerated the Bacchanalian nature of these parties."[42]

What is important in this example is not whether this revelous play really happened, but rather that, as Francis Darwin implies in his use of the term "exaggerated," their inclusion in the autobiography was a choice.[43] Even if Darwin really believed that his Cambridge life was overly riotous, he could have chosen to mute those details in his recollections. Instead, he clearly and purposefully emphasizes them. Why? In the earlier, highly influential tradition of Protestant spiritual autobiography, these bacchanals would likely have served as the beginning of Darwin's conversion process.[44] In such accounts of spiritual development, a "conviction of sin" is usually followed by "terror," "despair," and "news of the free and full salvation."[45] However, while Darwin's father's accusation that his son was idle might serve as the "conviction of sin," the later stages never follow. Rather than joining the clergy after Cambridge as planned, Darwin left on the *Beagle* expedition.[46]

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[42] C. Darwin, *The Autobiography of Charles Darwin*, 60. Van Wyhe agrees with Francis Darwin's assessment, positing that Darwin very likely drank very little as an undergraduate. As I have not yet discovered any direct evidence, I believe the truth probably lies somewhere between Darwin's account of profligacy and Van Wyhe's account of propriety (van Wyhe, *Charles Darwin in Cambridge*, 55).
[43] C. Darwin, *The Autobiography of Charles Darwin*, 60.
[44] Peterson, *Victorian Autobiography*, 2.
[45] John Henry Newman, "Autobiographical Memoir," in *Autobiographical Writings*, ed. Henry Tristram (New York: Sheed and Ward, 1957), 79.
[46] As Darwin describes it in *Recollections*, his career as a clergyman "died a natural death when on leaving Cambridge I joined the Beagle as Naturalist" (C. Darwin, *The Autobiography of Charles Darwin*, 57). For more on Darwin's journey to find a vocation, see James Secord, "The Discovery of a Vocation: Darwin's Early Geology," *The British Journal for the History of Science* 24, no. 2 (1991): 156.

What is clear is that Darwin has undergone some type of conversion between these bacchanals and his life as a scientific worker. Darwin's thankfulness at the end of *Recollections* that he has been largely spared in his adult life from "the distractions of society and amusement" suggests a dramatic shift from his life at Cambridge. But Darwin also avoids taking the credit for this transition, carefully avoiding any suggestion that it came through individual effort. Darwin describes his shift from overly playful youth to scientific worker as one which happened slowly and without any clear decision, on his part:

> I can now perceive how my love for science gradually preponderated over every other taste. During the first two years [of the *Beagle* expedition (1831-1833)] my old passion for shooting survived in nearly full force, and I shot myself all the birds and animals for my collection; but gradually I gave up my gun more and more, and finally altogether to my servant, as shooting interfered with my work, more especially with making out the geological structure of a country. I discovered, though unconsciously and insensibly, that the pleasure of observing and reasoning was a much higher one than that of skill and sport.[47]

The focus here is on Darwin's inner state, as one might expect of an autobiographical subject about to overcome his recreational vices. "Myself" was a later addition, as though to emphasize the deeply personal nature of the change which was about to occur.[48] But, oddly, Darwin situates himself at every time except the actual moment of 'conversion.' He is the observer situated long after the event ("I can now perceive"). He is the observed subject acting just before the event ("I shot myself; I gave up my gun more and more"). And he is the subject just beginning to attempt observing himself ("I discovered"). This last is particularly difficult to locate in time, as this observer performs the paradox of "discover[ing…] unconsciously and insensibly." It is evident that in this account that there is no one moment of revelation in which he realizes the worthlessness of his dissolute life and resolves to work harder.

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[47] C. Darwin, *The Autobiography of Charles Darwin*, 78-79.
[48] C. Darwin, "Recollections of the Development of My Mind and Character (Author's Fair Copy)," 52.

Rather, his emphasis on the gradualness of this transition, and the fact that the change supposedly occurred "unconsciously and insensibly," is clearly meant to mirror the gradualism of his evolutionary theory on the individual level. Like species change, he implies that the shift from nonscientific diversions to work was the result of slowly acting causes—largely independent of the actions of the individual—which could only be perceived after sufficient time had passed. As if this evolutionary language were not strong enough, Darwin also chose to add an addendum to this section in the fair copy: "The primeval instincts of the barbarian slowly yielded to the acquired tastes of the civilized man."[49] Just as, in *Descent of Man* (1871), Darwin claims that "Man [… has] risen, though not through his own exertions, to the very summit of the organic scale," here Darwin has 'risen' from 'barbarian' to 'civilized man', from idle sporting man into a scientific practitioner.[50] As was the case in his prescientific recreations, Darwin is clearly trying to suggest that the development out of his nonscientific diversions should be understood in Darwinian terms, as a matter of inheritance and natural law more than individual choice.

Darwin's description of this unwilled transition is especially interesting when compared to an account given by his Cambridge friend, J. M. Herbert. According to Herbert, Darwin gave up shooting *before* he left Cambridge, in response to a singular event which had everything to do with the morality of shooting. In Herbert's account, Darwin:

> had had two days' shooting at his friend's, Mr. Owen of Woodhouse; and that on the second day, when going over some of the ground they had beaten on the day before, he picked up a bird not quite dead, but lingering from a shot it had received on the previous day; and that it had made and left such a painful impression on his mind, that he could not reconcile it to his conscience to continue to derive pleasure from a sport which inflicted such cruel suffering.[51]

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[49] C. Darwin, "Recollections of the Development of My Mind and Character (Author's Fair Copy)," 53.
[50] Charles Darwin, *Descent of Man* (New York: Penguin, 2004), 689.
[51] F. Darwin, *Life and Letters of Charles Darwin* (New York: D. Appleton, 1887), 1:142.

These conflicting narratives should act as a reminder that, regardless of their truth, Darwin's account in his life writing was the result of deliberate choices about how he would present his recreations and work. Rather than taking a principled stand against the cruelty of shooting, Darwin instead downplays the issue of individual choice at the key moment of transition.

The evolutionary analogy Darwin employs suggests both difference between these two categories and similarity: his dissolute shooting becomes the foundation for his later scientific labours, and the vestiges of these recreational practices are still observable in this work. Darwin has handed his gun to his servant, but specimens must still be collected, and as Jordi Cat has argued, Darwin's "celebrated observational skills and attention to landscape" were likely developed by "young Darwin's hunting skills, the sharp eye acquired with the use of guns and scopes."[52] If, as Darwin admits, he cannot help looking back at his dissolute sporting days with pleasure,[53] it is at least in part because it seems that they too were a necessary part of his development. Despite appearing unrelated to his later scientific work, Darwin's bacchanals and idle sportsman-like behavior is a natural stage in his metamorphosis. But unlike *Descent of Man*, in which Darwin considers "a still higher destiny in the distant future,"[54] Darwin's changes as a scientific practitioner are completed once he becomes a scientific worker. Although he only officially claims this title in the last paragraph of his autobiography, once Darwin gives up his shooting, Darwin has become, at last, a "man of science."[55]

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[52] Jordi Cat, *Maxwell, Sutton, and the Birth of Color Photography* (New York: Palgrave Macmillan), 32. As Thomas Butler recalls, even when he was at Shrewsbury Darwin's shooting was spurred by Darwin's desire to examine the birds he shot (Thomas Butler, "Letter to Francis Darwin," DAR 112: A10-12, 13 Sep. 1882, Charles Darwin Papers, Cambridge University Library, University of Cambridge Library, Cambridge, U.K., 10).
[53] C. Darwin, *The Autobiography of Charles Darwin*, 60.
[54] C. Darwin, *Descent of Man*, 689.
[55] C. Darwin, *The Autobiography of Charles Darwin*, 144.

V. Entangled Work and Play at Down House

In *Recollections*, the story Darwin tells presents the scientific life as one in which various forms of play in youth can develop into adult scientific work. Some forms of play foreshadow the nature of his scientific work. Even diversions that may initially seem unrelated to science act as a natural stage for development into a scientific worker. However, when Darwin's *Recollections* are read within the context of the *Life and Letters of Charles Darwin*, the ways in which play and work structure his perception of his life do not come through as clearly. Darwin's own account of his life makes up only about 5% of the biography his son published, and it is largely overshadowed by the letters and personal reminiscences that also appear in this multi-volume biography. The *Life and Letters of Charles Darwin* mentions Darwin's work – particularly his "hard work" – so often that it is easy to forget the childhood recreations Darwin shared in his autobiography and to remember him solely as the hard-working adult scientist he claims he became.[56] Contemporary reviews of *Life and Letters of Charles Darwin* make clear that Darwin's devotion to hard work was one of the primary takeaways for Victorian readers. For example, the *Dublin Review* noted his "disinterested and untiring laboriousness" and *The Edinburgh Review* described Darwin as "working ever on and ever loving work."[57] *The Edinburgh Review* even highlighted that Darwin was inclined to over-work himself, including a quote from a letter to Sir James Sullivan, in which Darwin shared that "My scientific work tires

[56] See F. Darwin, *Life and Letters of Charles Darwin*, I:140, 199, 260, 271, 460, 516, 525, II:256, 325, 354.
[57] "Art. VII.--Darwin's Life and Letters," *Dublin Review* (April 1888): 340, in DAR 134.7, Apr. 1888, Charles Darwin Papers, Cambridge University Library, University of Cambridge, Cambridge, U.K.; "ART. V.--The Life and Letters of the Late Charles Darwin, F.R.S. With an Autobiographical Chapter. by His Son, Francis Darwin, F.R.S. Three vols. 8vo. London: 1887," *The Edinburgh Review, or Critical Journal* 342 (April 1888): 421, in DAR 134.1, Charles Darwin Papers, Cambridge University Library, University of Cambridge, Cambridge, U.K.

me more than it used to do, but I have nothing else to do, and whether one is worn out a year or two sooner or later signifies but little."[58]

Conversely, the *Life and Letters of Charles Darwin* also added an element that makes clear that the adult Darwin's life was not completely subsumed by his scientific labors. One of the most often discussed elements of the *Life and Letters of Charles Darwin* is Darwin's daily schedule, which notes that Darwin considered his "day's work" to be over around noon.[59] For some readers, this presents a very different image of Darwin's adult life. After the publication of the *Life and Letters of Charles Darwin*, the satirical magazine *Punch* mocked Darwin as a kind of fainéant, anxious about the naughtiness of his childhood recreations but unable to see that his adult life is one of idleness. In their account of a "Downy-Philosopher" (referencing Darwin's home, Down House) their Darwin analog (a creature portrayed as a seal-like missing link) recalls how, as an "exceptionally naughty boy," he claimed crab-apples can be grown by burying crabs.[60] This "naughtiness" continues into his adulthood, as he fails at a number of careers—skipping his Ordination Exam to hunt and mistakenly amputating a man's leg while learning medicine—before ending with his "success" as a man of science who works only three hours a day and gets drunk with Huxley in the afternoon. This image of Darwin as someone who knew how to avoid work continues today (albeit in a more positive light), in magazine articles like Alex Soojung-Kim Pang's "Darwin Was a Slacker and You Should Be Too" (2017). Pang presents Darwin not as an eager worker but rather as someone who wisely only worked just long enough to maximize his creativity.[61]

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[58] "ART. V.--The Life and Letters of the late Charles Darwin, F.R.S," *The Edinburgh Review*, 423.
[59] F. Darwin, *Life and Letters of Charles Darwin*, 91.
[60] "A Down-y Philosopher; Or, Memoirs of a Missing Link," *Punch, or the London Charivari* 93 (3 December 1887): 261 in Samuel Butler Collection (GBR/0275/Butler VIIII/4/3), St. John's College, Cambridge, U.K.
[61] Alex Soojung-Kim Pang, "Darwin Was a Slacker and You Should Be Too" *Nautilus*, 28 March 2017, https://nautil.us/darwin-was-a-slacker-and-you-should-be-too-6001/.

Both of these accounts are overstating the degree to which Darwin was a 'slacker.' *Punch*'s satirical account is clearly meant to be humorous, rather than a serious criticism of Darwin's daily practices. Darwin did not even drink much as an adult.[62] Pang's account also underestimates how much of Darwin's scientific work occurred at after the "end of his working day." As the *Dublin Review* noted, even after Darwin's "day's work" was done, he still did check his greenhouse and response to correspondents, which "must have been no slight daily labour; since, however idle or frivolous were his correspondents, every foolish letter was duly answered."[63] But the two possible interpretations of the *Life and Letters of Charles Darwin* – of Darwin as a zealous worker, sacrificing his health for his labor, and Darwin as the 'slacker,' working just enough and engaging in plenty of recreation – signal that Darwin's industriousness, in his autobiography, should be understood less as a description of his actual scientific practice as an adult, and more as an argument about what he saw as central to his identity, or even possibly as a marker of what characteristics he thought he had to emphasize in order to meet the norms of a scientific community that he referred to as his "fellow-workers."[64] In truth, Darwin's adult life involved both work and play.

The ways in which Darwin's *Recollections* did not fully capture his lived experiences became apparent to me on a trip I made to Down House in 2017. I went to Down House seeking out two of Darwin's play objects that presented minor mysteries: the backgammon board he played on with his wife Emma and the billiards table he used to distract himself from his work on *The Origin of Species*. I learned from this trip that Darwin's work and play as an adult could

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[62] F. Darwin, *Life and Letters of Charles Darwin*, I:96.
[63] "Art. VII.--Darwin's Life and Letters," *Dublin Review* (April 1888): 347, in DAR 134.7, Apr. 1888, Charles Darwin Papers, Cambridge University Library, University of Cambridge, Cambridge, U.K.
[64] C. Darwin, *The Autobiography of Charles Darwin*, 81.

not be easily disentangled. In the lives of scientific practitioners, playfulness may be disguised as work, and work may be mistaken for play.

As Francis Darwin shared with the public in his biography of his father, Charles and Emma Darwin would meet in their Down House drawing room every night to play backgammon, and “for many years a score of the games which each won was kept, and in this score [Charles Darwin] took the greatest interest.”[65] As Adrian Desmond and James Moore describe in their influential biography *Darwin* (1991), at one point in the autumn of 1869, during a visit from American botanist Asa Gray and his wife Jane, the games even became a “spectator sport”: “with Mrs[.] Gray cheering Emma’s gains and her husband consoling the loser. (‘Bang your bones’! Charles would explode in mock anger at his wife.)”[66] Compared to Darwin’s other recreations, historians and biographers have shown Darwin’s backgammon games an unusual degree of interest, frequently returning to this anecdote within biographical work.[67] But a detail shared in only a few of these works is that the backgammon board did not always look like an object to be

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[65] F. Darwin, *Life and Letters of Charles Darwin*, 1:101.
[66] Adrian Desmond and James Moore, *Darwin* (London: Michael Joseph, 1991), 562.
[67] Popular and scholarly biographies (marketed to both children and adults) which reference Darwin’s backgammon play include Ruth Moore’s *Charles Darwin: A Great Life in Brief* (New York: Alfred A. Knopf, 1955), 117, 190; Robert Cecil Olby’s *Charles Darwin* (London: Oxford University Press, 1967), 49; Peter Brent’s *Charles Darwin: ‘A Man of Enlarged Curiosity’* (London: Heinemann, 1981), 348, 459; Ronald W. Clark’s *The Survival of Charles Darwin* (London: Weidenfeld and Nicolson, 1984), 83; Renee Skelton’s *Charles Darwin and the Theory of Natural Selection* (Hauppauge, NY: Children’s Press Choice, 1987), 85; John Bowlby’s *Charles Darwin: a Biography* (London: Hutchinson, 1990), 410; Peter J. Bowler’s *Charles Darwin: The Man and His Influence* (Oxford: Blackwell, 1990), 93; Desmond and Moore’s *Darwin* (London: Michael Joseph, 1991); Rebecca Stefoff’s *Charles Darwin and the Evolution Revolution* (Oxford: Oxford University Press, 1996), 64; Janet Browne’s *Charles Darwin: The Power of Place* (New York: Knopf, 2002), 494; David Quammen's *The Reluctant Mr. Darwin: an Intimate Portrait of Charles Darwin's Making of His Theory of Evolution* (New York: Atlas Books, 2006), 241; David C. King’s *Charles Darwin* (New York: DK, 2007), 68; Margaret Jean Anderson’s *Charles Darwin: Naturalist* (Berkeley Heights, NJ: Enslow Publishers, Inc., 2008), 106-107; Cyril Aydon’s *A Brief Guide to Charles Darwin: His Life and Times* (Philadelphia: Running Press, 2008), 169; Ralph Colp Jr.’s *Darwin’s Illness* (Gainesville: University Press of Florida, 2008), 39, 118 ; John Van Wyhe’s *Darwin* (London: Andre Deutsch, 2008), 40; Tim M. Berra’s *Charles Darwin: The Concise Story of an Extraordinary Man* (Baltimore: John Hopkins University Press, 2009), 47; Deborah Heiligman’s *Charles and Emma: The Darwin's Leap of Faith* (New York: Henry Holt and Co., 2009), 132, 179, 217-218; Benjamin Wiker’s *The Darwin Myth: The Life and Lies of Charles Darwin* (Washington, D.C.: Regnery Publishing, 2009), 59; Kathleen Krull’s *Charles Darwin* (New York: Penguin, 2010), 122; Jerry Bergman’s *The Dark Side of Charles Darwin: A Critical Analysis of an Icon of Science* (Green Forest, AR: New Leaf Publishing Group, 2011), 90; Paul Johnson’s *Darwin: Portrait of a Genius* (New York: Viking, 2012), 60; Tim M. Berra’s *Darwin and His Children: His Other Legacy* (New York: Oxford University Press, 2013), 61, 62, 64; J. David Pleins’s *The Evolving God: Charles Darwin on the Naturalness of Religion* (New York: Bloomsbury, 2013), 41; and Andrew *Norman’s Charles Darwin: Destroyer of Myths* (New York: Pen and Sword, 2014), 68.

played with. As I learned while reading Janet Browne's biography *Charles Darwin* (2002), "the board was bound in leather to look as if it were a large book" when it was closed.[68]

Because I could not find any pictures of the backgammon board that showed the spine, I traveled to Down House hoping to verify Browne's claim and determine how effectively the backgammon board might have been disguised as part of Darwin's scientific work. Unfortunately, the backgammon board was lying open so that its spine was obscured, and it was roped off; however, a helpful curator was willing to let me wait until after closing, step past the rope, and quickly verify that the backgammon board could indeed be disguised as an object meant for work. I was asked not to take any pictures, but in Figure 5-2, I share a drawing I made of the board's state when I saw it. This backgammon board could indeed have been disguised among other books in Down House. Its ostensible title, *A History of America*, would fit in well alongside the books Darwin used in his research, such as Charles Lyell's *A Second Visit to the United States of North America* (1849) or Louis Agassiz's *Contributions to the Natural History of the United States of North America* (1857-62)).

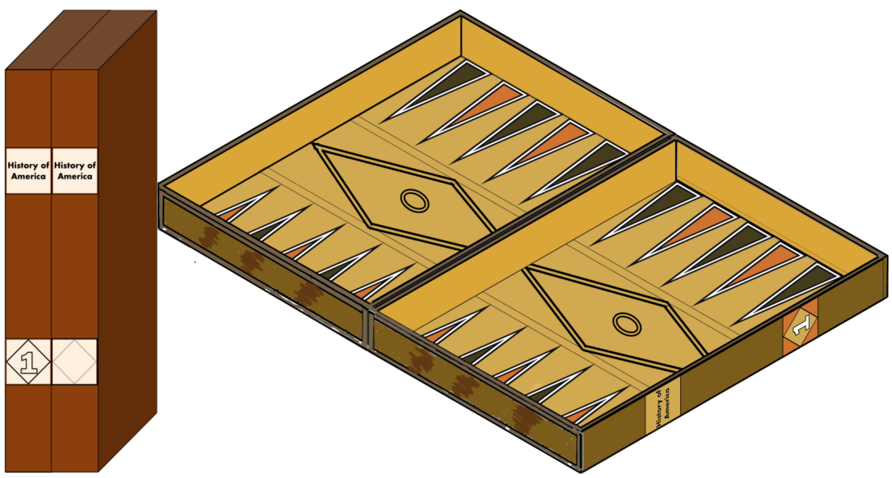

Figure 5-2: Sketch of the Darwin family backgammon board.

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[68] Janet Browne, *Charles Darwin: The Power of Place* (New York: Knopf, 2002), 494. Browne mistakenly describes the backgammon board as having the title *A History of North America*.

I do not mean to suggest that Darwin himself disguised this backgammon board to look like a tool for his work. The tradition of disguising backgammon boards as books began in the sixteenth century after Cardinal Wolsey declared the game immoral and ordered all backgammon boards to be burnt.[69] Many backgammon boards were designed with this aesthetic. Still, the backgammon board is a powerful illustration of the ways in which adult play – including the play of scientific practitioners – may be eclipsed by the appearance of work.

Unlike the backgammon board, Darwin's interest in billiards is not frequently discussed in work on Darwin. I was introduced to Darwin's interest in billiards as an adult through his letters and the biographical works by his children. In a series of letters, Darwin shares how he began playing the game in 1858,[70] and describes, at great length, the installation of a new billiard table in February of 1859.[71] He praises his son George's skill, even while he worries about the table making his sons "a set of Black-legs."[72] He invented his own game of billiards in May of 1859 and learned the American version of billiards in October of 1859, as a break whenever he was "weary of [his] work" on what he called "the horrid [*Origin of*] species."[73] Darwin continued playing billiards through December of 1860.[74] The story of the Darwins' billiard table

[69] Oswald Jacoby and John R. Crawford, *The Backgammon Book* (New York: Viking Press, 1970), 30.
[70] Darwin Correspondence Project, "Letter no. 2268," accessed on 18 February 2022, www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-2268.xml; Darwin Correspondence Project, "Letter no. 2414," accessed on 18 February 2022, https://www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-2414.xml.
[71] Darwin Correspondence Project, "Letter no. 2414"; Darwin Correspondence Project, "Letter no. 2420," accessed on 18 February 2022, https://www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-2420.xml.
[72] Darwin Correspondence Project, "Letter no. 2431," accessed on 18 February 2022, https://www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-2431.xml; Darwin Correspondence Project, "Letter no. 2483," accessed on 18 February 2022, https://www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-2483.xml..
[73] F. Darwin, *Life and Letters of Charles Darwin*, 1:506.
[74] Darwin Correspondence Project, "Letter no. 2442," accessed on 18 February 2022, https://www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-2442.xml; Darwin Correspondence Project, "Letter no. 2498," accessed on 18 February 2022, https://www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-2498.xml; Darwin Correspondence Project, "Letter no. 3014," accessed on 18 February 2022, www.darwinproject.ac.uk/letter/?docId=letters/DCP-LETT-3014.xml.

is completed in George Darwin's unpublished recollections of his father, where he describes how the table fell into disuse after 1876.[75]

I went to Down House hoping to find this object that further proved the adult Darwin did not literally 'never cease working.' Instead, I learned that the billiards table displayed at Down House was a similar table, rather than the original (which appears to have truly been lost). However, I also learned that the billiards table that Darwin says took his mind off his scientific work, and on which he played many games against his butler Parslow, was also used by Darwin as a space for laying out bird and rabbit skulls that he was studying.[76] While I had thought I was seeking out a play object that Darwin used to avoid his work, I found that I was instead looking for one of the tools he used to do his scientific work.

The lesson here is one that we have also seen in the previous chapters: not only did adult scientific practitioners still engage in recreations, but these recreations often cannot be easily disentangled from his scientific work. The scientific life that Darwin presents in *Recollections* makes an effective case for the value of playfulness as a child and young adult. Readers – whether the children and grandchildren Darwin ostensibly wrote his autobiography for or the readers who were later introduced to Darwin's life writing through the *Life and Letters of Charles Darwin* – may have found it reassuring to know that despite the emphasis on depicting science as hard work in the nineteenth century, playfulness still served an important function (even if only at the beginning stages of one's journey towards becoming a scientific worker). But *Recollections*' suggestion that development ends when work replaces play is also a limitation, as it may lead us to underestimate or ignore the role played by adult recreations.

[75] George Howard Darwin, [Addenda to 'Recollections of Charles Darwin'], CUL-DAR112.B24-B29, Darwin Online, http://darwin-online.org.uk/converted/manuscripts/Darwin_G_H_Recollections_CUL-DAR112.B24-B29.html.
[76] English Heritage, Audio Tour, Down House.

Postlude

The Preface to this dissertation encouraged readers to imagine the dissertation itself as a kind of play, with a label stating, “For Amusement Only.” In this dissertation, I have argued that even though science became more firmly tied to the idea of work in nineteenth-century Britain, scientific practitioners were still able to benefit from their play. I have made this case by exploring the play of several practitioners: play in James Ayrton Paris’s popular science text, *Philosophy in Sport Made Science in Earnest*, play with tops in the experiments of physicist James Clerk Maxwell, play in the famous “Maxwell’s Demon” thought experiment of Maxwell and physicist William Thomson (Lord Kelvin), and play in the autobiography of naturalist Charles Darwin. Having spent chapters analyzing the benefits of others’ play, it seems only fair to end by reflecting on my own “amusement.” What has been gained, through my study of scientific practitioners’ play? What changes should be made to make this play more rewarding in the future? And what is to be done once the amusement has ended?

I. Why Play This Game?

I first felt that this study of play and science had the potential to challenge assumptions (at the very least, my own) in the summer of 2015, while I was attending a dinner following a symposium of the Interdisciplinary Plant Group (IPG) at the University of Missouri – Columbia. I was not formally participating in this symposium: I had nothing to present and absolutely no background in the plant sciences. But a long-time friend of mine was organizing the event, and he graciously invited me along to meet some of the graduate student participants. A few months earlier I had begun reflecting on a fairly simplistic (but also, somehow, far too ambitious) version of this dissertation, and I thought that the dinner would provide an opportunity to reflect more on the value of recreations for scientists. As expected, the participants I met were kind and welcoming, and I found myself in conversation with an attendee about the kinds of scholarship we do. She told me about the research she was conducting on a certain species of plant, and I told her that it seemed like rich and rewarding work. I told her a bit about my study in the field of nineteenth-century Literature and Science (LS), using scholarship that considers the influence of scientific ideas on novels as my first example. But before I could even get to the topic of the dissertation I was considering, she enthusiastically told me that working in LS "sounds like fun": a response I thought about many times in the following days. Initially, my reflections on this interaction centered on why she had assumed my research in LS was fun. I want to be clear; I do truly enjoy the work I am able to do in LS. But she had no way of knowing that! Why had she assumed that my scholarship was fun? Was this a way of dismissing my research as frivolous? Was she saying that it seemed like a space where one could exercise their imagination? Was this a way of saying that this work sounded childish? Or did she make this assumption based on the interdisciplinary nature of my field, since activities that involve crossing disciplinary lines may be more easily thought of as forms of play? Eventually I realized that one can assign so many meanings and values to concepts related to play that I was never going to conclusively decipher her thought process. But perhaps I could better understand my own assumptions. I had come to the dinner specifically thinking about the relationship between science and play, and yet it had not occurred to me to describe her scientific research as "fun," even though I knew that plenty of people take great pleasure in nurturing and studying plants. I resolved that I needed a better understanding of what can be gained through a playful approach to science, if only so that I, too, could help to remind my fellow scholars that research – even in the sciences -- can be fun.

In *The Work of Playful Science in Nineteenth-Century Britain*, I have explored some of the background that explains why I so quickly labelled this plant sciences scholarship as "work." I began with scholarship on the history of nineteenth-century science, by scholars such as Lorraine Daston and Peter Galison, which argues that the association between science and hard work had its origin in that century and continues to shape the way the sciences are thought about today.[1] In this dissertation, I have provided further evidence to support this claim by investigating nineteenth-century British science writing. In Chapter One, I used word2vec natural language processing to create vector space models of collections of science writing texts. In these computational models, each word is placed in an n-dimensional space, such that words the algorithm judges to be more related to one another, within the corpus, are placed closer together. In the models for the volumes of *Nature*, the volumes of the *Philosophical Magazine,* and a collection of scientific life writing books, the term *science* was more closely associated with concepts related to work than to concepts related to play. However, in later chapters I also demonstrate that conceiving of science as work did not exclude playfulness from the sciences.

I have outlined some of the benefits of combining play and science, using nineteenth-century popular science texts aimed at young people as a starting point. In the vector space models created in Chapter One, one model stood apart: the model for my set of popular science texts aimed at young people was the only model in which science was more related to play than to work. Taking this as a sign that analyzing popular science might help to illuminate the benefits of play elsewhere, Chapter Two looked to one such text: John Ayrton Paris's *Philosophy in Sport*

[1] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010).

Made Science in Earnest. I demonstrated three "profits" that were gained by blending science and play in this text: readers were encouraged to craft scientific toys that help them see natural phenomena, playful absurdities promoted readers' engagement with the text, and the examples of playful science helped model how children might grow into scientific practitioners as adults. In Chapters Three, Four, and Five, I demonstrated that adult scientific workers, writing for audiences that included other adults, also found play "profitable" in these same ways. Physicist James Clerk Maxwell's experiments with color and dynamical tops allowed him to help other practitioners see scientific phenomena they otherwise might have missed. The playful absurdities of Maxwell and the physicist Lord Kelvin's descriptions of the Maxwell's Demon thought experiment encourage readers to consider the thought experiment multiple times. The naturalist Charles Darwin makes his childhood recreations an important part of the structure of his autobiography, suggesting that he felt that they had played an important role in his development into a scientific worker and demonstrating how others might follow his path. These benefits are not meant to encompass all possible reasons for scientific practitioners' play. But even this limited sample of the potentials for play in the sciences suggests that scientists should be encouraged to seek out opportunities to find the fun in their research.

In the Introduction to this dissertation, I claimed that our understanding of nineteenth-century British science is incomplete without consideration of the benefits of scientific practitioners' recreational pursuits. The examples of play that I have drawn attention to demonstrate that some actions of scientific practitioners would be much harder to explain without awareness of the benefits of play in the sciences. For example, Maxwell's decision to describe his color top as a *top* instead of *discs* makes sense only if one accepts that he was injecting some playfulness into a tedious experiment, which helped keep viewers engaged so that they could evaluate what colors they were seeing. Moreover, my focus on play in the sciences has provided a much-needed counterpoint to scholarship commenting on the close association of science and work in the nineteenth century. Take, for example, Daston and Galison's claim that it was not until the late-nineteenth and early-twentieth century that scientific practitioners stopped focusing on describing science as hard work, and instead "professed themselves unable to distinguish between work and play," making discoveries through "quasi-ludic promptings of well-honed intuitions."[2] This use of the word "professed" — which can mean either to affirm, to confess, or to pretend[3] — leaves it ambiguous whether or not Daston and Galison believe this confusion was real. A reader might conclude that Daston and Galison are suggesting that playfulness and the sciences are incompatible, which is why these scientific intuitions can only be "quasi-ludic." I am, to be clear, not arguing that Daston and Galison do believe that play has had no place in the sciences. But this example illustrates how a focus on science as work, without clear examples of playful science, can tend to eclipse the possibility of play in the sciences and make it difficult to see that there are types of scientific practice that might not be labelled as scientific *work*.

As I worked on this dissertation, I observed two trends that make an understanding of the benefits of playful science even more valuable. In recent years, a number of works have been published advocating for more intentional integration of play into classrooms, such as Lindsay Portnoy's *Game On? Brain On! The Surprising Relationship between Play and Gray (Matter)* (2020) and Michael Matera and John Meehan's *Fully Engaged: Playful Pedagogy for Real Results* (2021). The pedagogical challenges caused by the COVID-19 pandemic have inspired

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[2] Daston and Galison, *Objectivity*, 46.
[3] "Profess, v," in *Oxford English Dictionary*, www.oed.com/view/Entry/152045?rskey=0CnFmj&result=3&isAdvanced=false.

teachers from many disciplines and at many educational levels to consider less traditional teaching methods, including adding more play and games to their courses.[4] If the activities of professional scientists continue to be thought of solely as a form of work, students may interpret playfulness in the science classroom as an alternative to "real" science and therefore might view it as less valuable than more rigorous work. If, however, students (and teachers) learn about the benefits that scientific practitioners like Maxwell found in their recreations, they may come to see play in the science classroom as training for the kinds of play students could later engage in as a scientist, lessening the buy-in for these teaching practices.

Another trend I have observed is an increasing number of attempts to foster public engagement with and contribution to the sciences. As Donna Haraway notes in *Staying with the Trouble* (2016), playfulness can be an effective way of asking communities to engage with even bleak scientific ideas, such as spiraling ecological devastation. Pointing to the Crochet Coral Reef project – a collaborative art project in which thousands of people work together to replicate a variety of healthy and damaged reefs through crochet, while celebrating the mathematical aesthetics of coral reefs – Haraway argues that "material play builds caring publics."[5] In the case of the Crochet Coral Reef project, play allows human beings to practice caring for their nonhuman brethren without the need for proximity.

Digital forms of play have also been used to help non-experts learn to care about and contribute to the sciences. *iNaturalist*, a crowdsourced platform launched in 2008, allows anyone

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[4] See, for example, Elvira G. Rincon-Flores and Brenda N. Santos-Guevara, "Gamification during Covid-19: Promoting Active Learning and Motivation in Higher Education," *Australasian Journal of Educational Technology* 37, no. 5 (2021); Francisco Antonio Nieto-Escamez and María Dolores Roldán-Tapia, "Gamification as Online Teaching Strategy During COVID-19: A Mini-Review," *Frontiers in Psychology* 12 (2021); Matthew T. Fontana, "Gamification of ChemDraw during the COVID-19 Pandemic: Investigating How a Serious, Educational-Game Tournament (Molecule Madness) Impacts Student Wellness and Organic Chemistry Skills while Distance Learning," *Journal of Chemical Education* 97, no. 9 (2020).
[5] Donna Haraway, *Staying with the Trouble* (Durham: Duke University Press, 2016), 79.

with a smartphone to document the organisms they see in their day. Although the platform was already used as a recreation by many users, *iNaturalist* further encouraged users to see the playfulness of the platform by creating the app *Seek by iNaturalist* in 2018, which lists nearby organisms and encourages users to meet certain challenges to earn badges.[6] *Foldit*, an online puzzle video game released in 2008, provides players with proteins to fold, and passes the highest scoring solutions on to researchers to help tackle problems like protein structure prediction.[7] *Phylo* is an online pattern matching video game, released in 2010, which asks players to compare the genomes of various species; high scores are sent to the McGill Centre for Bioinformatics to further optimize a computer algorithm for matching sequences.[8] *EteRNA*, also released in 2010, is an online video game that asks users to solve puzzles related to the folding of RNA.[9] More recently, developers have begun bringing these kinds of citizen science games into other, existing video games, such as *Eve Online* (2003) and *Borderlands 3* (2019).[10] Sharing stories about the value of play for scientific practitioners might encourage more people to join these citizen science games, after reflecting on the value their own recreations might have.

While there are a lot of reasons to play this particular game – studying the playful science of nineteenth-century scientific practitioners – I would not be staying true to the spirit of this dissertation if I did not end by noting that one important benefit of this research has been that, despite the anxiety, frustrations, and discouragements I have sometimes felt as I completed this project, I have had fun. It was fun to stand over Darwin's backgammon board and picture the games he and Emma played. It was fun to try to imagine the absurd characteristics of Maxwell's

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[6] Carrie Seltzer, "Seek by iNaturalist," *iNaturalist*, 27 Oct. 2021, https://www.inaturalist.org/pages/seek_app.
[7] "The Science Behind Foldit," *Foldit*, https://fold.it/portal/info/about.
[8] Jérôme Waldispühl et al., *Phylo*, 2022, https://phylo.cs.mcgill.ca/index.html#about.
[9] *EteRNA*, https://eternagame.org/.
[10] "Project Discovery," *EVE Online*, 2022, https://www.eveonline.com/discovery; "Play Borderlands Science Today!," *Borderlands 3*, https://borderlands.com/en-US/news/2020-04-07-borderlands-science/.

Demon. I had fun learning how to spin Maxwell's tops and Paris's thaumatropes. And I had fun creating the vector space models discussed in Chapter One. Too often computational literary studies are justified by emphasizing that they are more than a form of play. For example, Johanna Drucker has stated that popular media have embraced distant reading because it loves studies of big trends, but that distant readings are "not just novelty acts that amuse us."[11] Computational studies certainly are not *only* amusement; however, I found that computational studies were a low-stakes space for me to test ideas that I was willing to return to repeatedly, even when working on this dissertation became daunting. The surprise of seeing what the models looked like was genuinely enjoyable. I hope that my readers, too, found entertainment in reading about these recreations.

II. Patches and Expansion Packs

Despite the fun this dissertation allowed, there are still changes I would make, were I starting this game all over again. In the video game industry, companies routinely provide new software for their games: patches that address unexpected flaws and expansion packs that allow new kinds of play. Here are some of the patches and expansions that I might introduce if I were releasing *The Work of Playful Science* version 2.0.

In Chapter One, "Locating Work and Play in Four Genres of Nineteenth-Century Scientific Writing," I discussed several of the limitations of my approach. I pointed out that the size of my datasets for popular science books aimed at youth and scientific life writing in the nineteenth century paled in comparison to the many works that were published. I noted that the optical character recognition used when creating digital versions of print texts introduces errors.

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[11] Johanna Drucker, "Why Distant Reading Isn't," *PMLA* 132, no. 3 (2017): 630.

And I described how the parameters used in the creation of the vector space models can affect the results, so choosing the best parameters comes down in the end to human judgement. These are issues that can never be completely solved. It would be impossible to find digital copies of every popular science book. And guaranteeing a dataset completely free of errors would require immense resources. However, more time spent on these models – time to look for errors, find new texts to add to the corpora, and create more models to determine the best parameters – would certainly help to reduce the degree to which these elements are biasing the vector space models.

Chapter One also helps to illustrate a more serious issue for this study of play in the sciences. In my discussion of the scientific life writing corpus, I noted that it was difficult to find examples in this genre of scientific practitioners who did not come from the group known as "gentlemen of science," which is to say, white men from either professional classes or landed gentry. Unfortunately, the scientific practitioners discussed in this dissertation represent a very narrow segment of nineteenth-century Britain. Little is known about Paris's father, but he was considered a gentleman.[12] Maxwell's father was a lawyer who inherited an estate at Glenlair (along with the family name Maxwell). William Thomson's father was a professor at the University of Glasgow. Darwin's father had an established medical practice. It is often easiest to study figures from these types of backgrounds. The writings and materials of gentlemen of science have been better preserved. However, the results of their play are most likely not universally applicable.

As play theorist Sebastian de Grazia noted, play is often just a name for activities which occur under certain conditions of access to leisure and freedom of choice: conditions not

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[12] William Munk, *A Memoir of the Life and Writings of John Ayrton Paris* (London: Bell and Daldy, 1857), 7.

available to all.[13] In nineteenth-century Britain, white racism, class divisions, and sexism restricted who was invited to play and what forms their play could take. Racist discourse argued that the recreations of people of color were less civilized and used this claim to suggest that people of color needed to be 'taught to labor.'[14] A lack of economic security would have excluded many from being able to engage in forms of play that required disposable income, such as the toys Mr. Seymour purchases for his family in *Philosophy in Sport*. And women's recreations might be constrained by expectations about what kinds of play were appropriate for them. For example, Jeremy Bentham argued that women naturally enjoyed recreations that kept them indoors, while men's recreations kept them outside.[15] I have already demonstrated, in Chapters Three and Four, how the gendering of play objects such as tops and cricket bats influenced how these objects might be interpreted within a community of "men of science." Social identities held by scientific practitioners could change how their playfulness is interpreted by others in the scientific community. These limitations help to explain why I very rarely came across examples of playfulness from female practitioners or from scientific practitioners of color. Within the nineteenth-century, every example of a playful approach to science from a female practitioner that I found came from a popularizer, such as Mary or Elizabeth Kirby. I heard of few examples even outside nineteenth-century Britain.[16]

While this gap in this study is explicable, it is also something I hope can eventually be corrected. It seems very unlikely that there are *no* examples of the play of scientific practitioners

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[13] Sebastian de Grazia, *Of Time, Work, and Leisure* (Garden City, New York: Anchor Books, 1962), 356.
[14] Ta-Nehisi Coates, *We Were Eight Years in Power* (New York: One World, 2017), 178.
[15] Jeremy Bentham, *Theory of Legislation*, ed. C. K. Ogden (London: Routledge & Kegan Paul, 1950), 39.
[16] Catherine Heise provides a few examples of female physicists reflecting on their play in her study of how physicists in the twenty-first century (like Darwin in the nineteenth) often view their childhood experiences as some of their first steps into their professional identities (Heise, "Learning and Transition in a Culture of Playful Physicists," *European Journal of Psychology of Education* 23, no. 2 (2008).

who are not 'gentlemen of science' in the nineteenth century. I remain hopeful that these histories could be recovered. It is possible that play will prove less beneficial, in these cases. As Matthew Kaiser notes in *The World in Play*, "marginalized, disempowered, or unconventional people tend to bear the brunt of modernity, and are thus exposed in a very personal way to the dark side of play, like no one else."[17] But if evidence is found that playfulness is a liability for other scientific practitioners, rather than a potential opportunity, it would offer an essential counterpoint to the work I have done so far.

In Chapter 2, "The Profits of Play in John Ayrton Paris's *Philosophy in Sport*," I used one popular science book aimed at youth to illuminate some of the benefits play might have in the sciences. However, a study of more works in this genre might help to illuminate more benefits. There are several promising candidates in the list of popular science texts in Appendix A. Of particular note is John Henry Pepper's *The Boy's Playbook of Science* (1859), which was also widely read in the nineteenth century. *The Boy's Playbook of Science* sold about 34,000 copies by the end of the nineteenth century, which is comparable to the 35,000 copies of Darwin's *Descent of Man* (1871) that were sold by the end of the century.[18] Examples of playful science in popular science texts that were not first published in nineteenth-century Britain, such as John Newbery's influential *Newtonian System of Philosophy* (1761), might also prove illuminating.

In Chapter Three, "Play and Experiments on Perception: James Clerk Maxwell and the Secret of the Top," I demonstrated how Maxwell uses play objects to make natural phenomena visible for his audience. Maxwell is often presented as a particularly playful scientific figure, and it may be tempting for some to assume his uses of play were idiosyncratic. One way to expand

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[17] Matthew Kaiser, *The World in Play: Portraits of a Victorian Concept* (Stanford: Stanford University Press, 2012).
[18] Bernard Lightman, *Victorian Popularizers of Science* (Chicago: University of Chicago Press, 2007), 490.

on the work I have done would be to emphasize that Maxwell was not alone in using play objects in this way. For example, Scottish chemist Alexander Crum Brown's knitted models of "interpenetrating surfaces," referenced in his presentation to the Royal Society of Edinburgh, "On a Case of Interlacing Surfaces" in 1885, seems to have benefits similar to Maxwell's play with tops.[19] Nor was this solely the purview of nineteenth-century science. Mathematical biologist D'Arcy Thomson entertained children by drawing dogs on rubber sheets and stretching poodles into dachshunds, which eventually developed into his work *On Growth and Form* (1917).[20] Even Isaac Newton benefitted from playing with objects. In 1672, Newton wrote a letter to the Royal Society in which he recounted recent experiments he had conducted with his prism. In the letter, he describes how he initially treated his refraction of light as "a very pleasing divertissement, to view the vivid and intense colours produced thereby."[21] However, this fun soon shifted to circumspection, as he found that the shape of the refracted light was not what he expected. The result was that he conducted more experiments and determined that "Light consists of Rays differently refrangible," or as it would be put it today, visible light consists of different wavelengths.[22] As in the work of Maxwell, play with an object one might consider a toy, a prism being used as a diversion, helped Newton make observations he might otherwise have missed.

While completing work on Chapters Four and Five, I often found myself reflecting on the value of play in different disciplines. As I noted in Chapter Four, "Maxwell's Demon, Kelvin's Cricket Bats: Playful Absurdity in Thought Experiments," Maxwell's Demon is not the only

[19] Alexander Crum Brown, "Unfinished Nineteenth-Century Knitting Projects?," c. 1885, Whipple Museum, University of Cambridge, Cambridge, U.K.
[20] Stephen Wolfram, "Are All Fish the Same Shape If You Stretch Them? The Victorian Tale of *On Growth and Form*," *The Mathematical Intelligencer* (September 11, 2018).
[21] Isaac Newton, "A Letter of Mr. Isaac Newton," *Philosophical Transactions* No. 80 (19 February 1672): 3076.
[22] Newton, "A Letter of Mr. Isaac Newton," 3079.

thought experiment that includes superfluous details that might encourage someone to reconsider the thought experiment multiple times. I pointed to Schrodinger's cat as an example, but also to Judith Jarvis Thomson's "unconscious violinist" thought experiment from the field of philosophy, suggesting that thought experiments outside the sciences might also benefit from playfulness. In Chapter Five, "Diversion or Development? Play and the Scientific Life in Charles Darwin's Recollections," I discussed how Darwin tied his play to his development as a scientific worker. But Darwin was not alone in doing this. Life writing in other fields also made childhood play part of professional development. For example, in *The Life of Charlotte Brontë* (1857), Elizabeth Gaskell includes accounts of the young Brontës' "plays and amusements"—writing tales, dramas, poems, and romances—suggesting that they were part of Charlotte Brontë's development into a novelist.[23] Similarly, William Gershom Collingwood's *The Life and Work of John Ruskin* (1893) details how Ruskin invented a game in which he stared at "patterns on carpets" as a child, preparing him for his later work as an art critic.[24] At several points during the writing of this dissertation, I found myself tempted to expand my focus and reflect on the benefits of play in non-scientific disciplines. As fun as that sounded, I determined that was really an entirely different dissertation that I simply did not have time to write: perhaps one titled *The Work of Play in the Arts and Humanities*. However, now that version 1.0 of *The Work of Playful Science in Nineteenth-Century Britain* is coming to a close, it is worth considering how parallel benefits of play in other fields might enrich the discussion of play in the sciences.

It would also be valuable to begin reflecting on the ways in which different scientific disciplines may have different relationships with the concepts of play and work. Some scientific

[23] Elizabeth Gaskell, *The Life of Charlotte Brontë*, (Smith, Elder, and Co., 1906).
[24] William Gershom Collingwood, *The Life and Work of John Ruskin* (London: Methuen & Co., 1893), 1:17.

disciplines, such as geology, kept their associations with gentlemanly leisure for longer than others.[25] Some, such as botany, became popular as recreations for amateurs because they required fewer resources. Most of the practitioners I discuss in detail were writing about the physical sciences, with Darwin's biological work being the only outlier. Further discussion of examples of play in the sciences might reveal that some disciplines were more amenable to some benefits than to others. Appendix B demonstrates that there are plenty of other scientific life writing works that provide scientific practitioners that might be used as a jumping off point for reflection on other disciplines.

The main takeaway here is that there are many exciting options for the future study of play in the sciences. There are many examples of scientific practitioners at play that I haven't even had time to mention yet, such as the parlor games played at meetings of the Geological Society of London, Humphry Davy having fun with nitrous oxide, Peter Guthrie Tait applying his knowledge of physics to his golf swing, Charles Vernon Boys blowing soap bubbles, August Kekulé's dream of gamboling atoms that led to the discovery of benzene rings, Claude Shannon juggling and thinking about unicycles, Richard Feynman joking and playing pranks, James Watson's self-described "play" with the structure of DNA, and A.F.W. Edwards's use of tennis balls to create complex diagrams.[26] Of course, the patches and expansions that I have suggested

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[25] Adelene Buckland, *Novel Science: Fiction and the Invention of Nineteenth-Century Geology* (Chicago, University of Chicago, 2013), 10.

[26] See Buckland, *Novel Science*, 31-33; Sharon Ruston, "The Art of Medicine: When Respiring Gas Inspired Poetry," *The Lancet* 381 (2013): 367; Peter Guthrie Tait, "The Unwritten Chapter on Golf," *Nature* 36 (1887); Charles Vernon Boys, "Experiments with Soap-Bubbles," *Proceedings of the Physical Society of London* 9 (1887): 189; W. H. Leatherdale, *The Role of Analogy, Model, and Metaphor in Science* (Amsterdam: North-Holland Publishing Company, 1974), 20; Jimmy Soni and Rob Goodman, *A Mind at Play: How Claude Shannon Invented the Information Age* (New York: Simon & Schuster, 2017); Richard P. Feynman, *"Surely You're Joking, Mr. Feynman"* (New York: W. W. Norton, 1997), 200; James Watson, *The Double Helix* (New York: Simon & Schuster, 1996), 50-51; Anthony Edwards, "A Tennis Ball, 1988," Whipple Museum, University of Cambridge, Cambridge, U.K.

might be implemented are far too much for one scholar to take up on their own. So, I would like, now, to switch metaphors.

The Work of Playful Science in Nineteenth-Century Britain is a puzzle. In this dissertation, I have put together enough pieces to see some of the picture. It is an image of nineteenth-century science that absolutely has space for playfulness. But there are still missing pieces. Puzzles are enjoyable solitary play. In the future, I hope to place some of the pieces I described above into the puzzle, filling out the picture more. But I have found that for me, the real joy in a puzzle comes after I convince others to join me in solving it. I hope that the research I have done so far and my discussion of the places this study might go have made a convincing case for the value of joining in this form of amusement.

III. Play as Prelude

I have titled the conclusion to this dissertation the "postlude," which would seem to suggest that I am now moving to a stage after the ludic. I have demonstrated that even though science was in fact closely associated with work in nineteenth-century Britain, scientific practitioners still benefitted from playfulness in various ways. The play, it would seem, is now at an end. Or is it?

I have increasingly found myself meditating on a quote that came decades after my area of focus, and from an ocean away. American designers Charles and Ray Eames played an important part in the development of modern architecture, furniture, and industrial design. From one point of view, the Eames's were dedicated workers, completing thirteen-hour workdays in the Eames Office in L.A.[27] But by this point in this dissertation, it should come as no surprise

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[27] Catherine Slessor, "Charles Eames (1907–1978) and Ray Eames (1912–1988)," *The Architectural Review*, 2015, www.architectural-review.com/essays/reputations/charles-eames-1907-1978-and-ray-eames-1912-1988.

that the Eames's were also famous for their playfulness. They recognized play's potential to spur learning and its ability to lead to innovation. One of their key insights was that "Toys are not really as innocent as they look. Toys and games are the preludes to serious ideas."[28] In this Postlude, I have discussed some of the important effects a better understanding of playful science might have and raised some serious issues that would need to be considered in future research, such as the dearth of examples of play from scientific practitioners with marginalized social identities. There are certainly serious ideas to be considered. And yet I find myself focused on the Eames's use of *prelude*. *Prelude* is an odd word. In its Middle French antecedent, a *prélude* is "a series of notes sung or played to exercise the voice or practice a musical instrument."[29] In that sense, a prelude is play that comes before further play.

Is it possible to play, even while considering "serious ideas"? In *Staying with the Trouble*, Haraway argues that it is. Even when discussing topics as serious as ecological disaster, Haraway posits that "perhaps it is precisely in the realm of play, outside the dictates of teleology, settled categories, and function, that serious worldliness and recuperation become possible."[30] The best move, then, seems to me to be to keep the play going – to keep seeking out examples of playful science and reflecting on its benefits while maintaining a playful spirit of inquiry. I can't predict with certainty what other serious ideas further study of play and science might uncover. Continuing to play with the idea of playful science is, in Paris's language, an investment, but the return is uncertain. But I can say with certainty that future study of play will remain fun.

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[28] Marlow Hoffman, "Five Things Charles & Ray Eames Teach Us About Play," *Eames Official Site*, accessed March 3, 2021, www.eamesoffice.com/blog/five-things-charles-ray-eames-teach-us-about-play/#:~:text=2)%20Toys%20are%20a%20prelude,as%20innocent%20as%20they%20look.&text=He%20said%2C%20'This%20toy%20is,that%20they%20designed%20their%20own.

[29] "Prelude, n." in *Oxford English Dictionary*, Oxford University Press, www.oed.com/view/Entry/150227?rskey=xRy0dr&result=1&isAdvanced=false.

[30] Haraway, *Staying with the Trouble*, 23-24.

Appendix A – Texts Included in Corpus of Nineteenth-Century British Popular Science Books for Young Readers (1800-1900)

A Sequel to Endless Amusement, Containing Nearly Four Hundred Interesting Experiments, in Various Branches of Science. London: Thomas Boys, 1825. Google Books.

Anderson, John Henry. *The Fashionable Science of Parlour Magic; Being the Newest Tricks of Deception, Developed and Illustrated; with an Exposure of the Practices Made Use of by Professional Card Players, Blacklegs, and Gamblers: To Which Is Added, for the First Time, the Magic of Spirit Rapping, Writing Mediums, and Table Turning, &C., &C*. London: R. S. Francis, 1855. Google Books.

Badcock, John. *Philosophical Recreations, or Winter Amusements*. London: T. Hughes, 1820. Hathi Trust.

Ball, Robert Stalwell. *Star-Land. Being Talks with Young People About the Wonders of the Heavens*. London: Cassell, 1889. Hathi Trust.

Brewer, Ebenezer Cobham. *Theology in Science*. London: Jarrold and Sons, 1860. Google Books.

Brightwen, Mrs. *Glimpses into Plant-Life: An Easy Guide to the Study*. London: T. Fisher, 1897. Google Books.

---. *Rambles with Nature Students*. London: Religious Tract Society, 1899. Google Books.

---. *Wild Nature Won by Kindness*. London: T. Fisher, 1892. Google Books.

Buckley, Arabella B. *The Fairy-Land of Science*. London: Stanford, 1880. Hathi Trust.

---. *Life and Her Children: Glimpses of Animal Life from the Amoeba to the Insects*. London: E. Stanford, 1881. Hathi Trust.

---. *A Short History of Natural Science and the Progress of Discovery from the Time of the Greeks to the Present Day for the Use of Schools and Young Persons*. 2nd ed. London: Stanford, 1879. Hathi Trust.

---. *Through Magic Glasses and Other Lectures*. London: Stanford, 1890. Hathi Trust.

---. *Winners in Life's Race or the Great Backboned Family*. London: Stanford, 1882. Hathi Trust.

Carey, Annie. *The Wonders of Common Things*. London: Cassell, Petter, and Galpin, 1873. Google Books.

Clark, Samuel. *Peter Parley's Wonders of the Earth, Sea, and Sky*. Edited by Rev. T. Wilson. London: Darton and Clark, 1837. Google Books.

Faraday, Michael. *Chemical Manipulation; Being Instructions to Students in Chemistry, on the Methods of Performing Experiments of Demonstration or of Research, with Accuracy and Success*. London: W. Phillips, 1827. Hathi Trust.

---. *Lectures on the Various Forces of Matter, and the Chemical History of a Candle*. London: Griffin Bohn & Co., 1863. Hathi Trust.

Forrest, George. *Every Boy's Book: A Complete Encyclopædia of Sports and Amusements: Intended to Afford Recreation and Instruction to Boys in Their Leisure Hours*. London: G. Routledge & Co., 1855. Hathi Trust.

Gatty, Margaret. *Parables from Nature.* London: George Bell, 1896. Hathi Trust.

Giberne, Agnes. *Among the Stars: Or, Wonderful Things in the Sky*. London: Seeley, 1885. Google Books.

---. *The Ocean of Air: Meteorology for Beginners*. London: Seeley and Co, 1890. Google Books.

---. *Radiant Suns: A Sequel to Sun, Moon and Stars*. London: Seeley, 1895. Hathi Trust.

---. *The World's Foundations or Geology for Beginners*. London: Seeley, Jackson, & Halliday, 1882. Google Books.

Gosse, Philip Henry. *Evenings at the Microscope; or, Researches among the Minuter Organs and Forms of Animal Life*. London: D. Appleton, 1883. Hathi Trust.

Grindon, Leo H. *Country Rambles, and Manchester Walks and Wild Flowers: Being Rural Wanderings in Cheshire, Lancashire, Derbyshire, & Yorkshire*. Manchester: Palmer & Howe, 1882. Hathi Trust.

Hack, Maria. *Lectures at Home*. London: Darton and Harvey, 1841. Google Books.

Harper, John. *The Sea-Side and Aquarium, or, Anecdote and Gossip on Marine Zoology*. Edinburgh: William P. Nimmo, 1858. Hathi Trust.

Henslow, George. *Botany for Children*. London: Edward Stanford, 1880. Google Books.

Houghton, William. *Country Walks of a Naturalist*. London: Groombridge and Sons, 1869. Google Books.

---. *Seaside Walks of a Naturalist with His Children*. London: Groombridge and sons, 1870. Hathi Trust.

Johns, C. A. *Bird's Nests*. London: Society for Promoting Christian Knowledge, 1854. Hathi Trust.

---. *Botanical Rambles*. London: Society for Promoting Christian Knowledge, 1846. Hathi Trust.

Joyce, Jeremiah. *Scientific Dialogues, Intended for the Instruction and Entertainment of Young People, in which the First Principles of Natural and Experimental Philosophy Are Fully Explained*. Vols. 2 – 5. London: J. Johnson, 1809. Hathi Trust.

Kingsley, Charles. *Madam How and Lady Why, or, First Lessons in Earth Lore for Children*. London: Bell and Daldy, 1870. Hathi Trust.

---. *Town Geology*. London: Daldy, Isbister & Co., 1878. Hathi Trust.

Kirby, Mary and Elizabeth Kirby. *Aunt Martha's Corner Cupboard: A Story for Little Boys and Girls*. London: T. Nelson and Sons, 1875. Hathi Trust.

Loudon, Mrs. *The Entertaining Naturalist Being Popular Descriptions, Tales, and Anecdotes of More Than Five Hundred Animals*. London: H.G. Bohn, 1843. Hathi Trust.

---. *The Young Naturalist's Journey; or, the Travels of Agnes Merton and Her Mama*. London: William Smith, 1840. Hathi Trust.

Marcet, Jane Haldimand. *Conversations on Chemistry*. 2 vols. London: Longman, Hurst, Rees, Orme, and Brown, 1817. Google Books.

---. *Conversations on Vegetable Physiology: Comprehending the Elements of Botany, with Their Application to Agriculture*. 2 vols. London: Longman, Rees, Orme, Brown, and Green, 1829. Hathi Trust.

Moffatt, John M. *The Book of Science; a Familiar Introduction to the Principles of Natural Philosophy*. London: Chapman and Hall, 1834. Google Books.

Paris, John Ayrton. *Philosophy in Sport Made Science in Earnest; Being an Attempt to Illustrate the First Principles of Natural Philosophy by the Aid of Popular Toys and Sports*. 3 vols. London: Longman, Rees, Orme, Brown, and Green, 1827. Hathi Trust.

Parlour Magic: A Manual of Amusing Experiments, Transmutations Sleights and Subtleties, Legerdemain, & c. For the Instruction of Youth. London: D. Bogue, 1853. Hathi Trust.

Pepper, John Henry. *The Boy's Playbook of Science: Including the Various Manipulations and Arrangements of Chemical and Philosophical Apparatus Required for the Successful Performance of Scientific Experiments, in Illustration of the Elementary Branches of Chemistry and Natural Philosophy*. 2nd ed. London: Routledge, Warne, and Routledge, 1860. Hathi Trust.

---. *The Playbook of Metals; Including Personal Narratives of Visits to Coal, Lead, Copper, and Tin Mines; with a Large Number of Interesting Experiments Relating to Alchemy and the Chemistry of the Fifty Metallic Elements*. London: Routledge, Warne, and Routledge, 1861. Hathi Trust.

---. *Scientific Amusements for Young People*. London: Routledge, Warne, and Routledge, 1861. Google Books.

Proctor, Richard A. *Elementary Physical Geography*. London: Casell, Petter, and Galpin, 1873. Google Books.

---. *Lessons in Elementary Astronomy*. London: Cassell, Petter, and Galpin, 1871. Google Books.

The Playmate: A Pleasant Companion for Spare Hours. Ed. Joseph Cundall. London: Old Bond Street, 1847. Hathi Trust.

Tissandier, Gaston. *Popular Scientific Recreations in Natural Philosophy, Astronomy, Geology, Chemistry*. London: Ward, Lock, 1883. Hathi Trust.

Tissandier, Gaston and Henry Frith. *Half Hours of Scientific Amusement: Practical Physics and Chemistry without Apparatus*. London: Ward, Lock, 1890. Hathi Trust.

Tomlinson, Sarah Windsor. *First Steps in General Knowledge: The Starry Heavens*. London: Society for Promoting Christian Knowledge, 1846. Google Books.

Winslow, Forbes Edward. *The Children's Fairy Geography, or, a Merry Trip Round Europe*. London: W. Skeffington & Son, 1880. Hathi Trust.

Wood, John George. *The Boy's Own Book of Natural History*. London: Routledge, 1867. Hathi Trust.

---. *The Modern Playmate: A Book of Games, Sports, and Diversions for Boys of All Ages*. London: Frederick Warne, 1870. Google Books.

Wright, Mrs. *What Is a Bird? The Forms of Birds, Their Instinct, and Use in Creation Considered*. London: Jarrold and Sons, 1857. Google Books.

Appendix B – Texts Included in Corpus of Scientific Life Writing Corpus (1800-1900)

Allen, Grant. *Charles Darwin*. Ed. Andrew Lang. London: Longmans, Green, and Co., 1885. Hathi Trust.

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